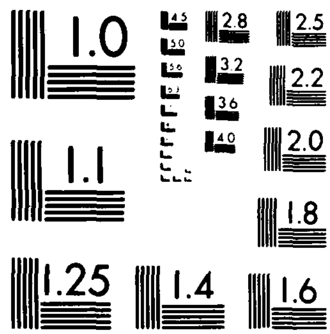
AD-A188 844 STANDARDIZATION: USING COMPARATIVE MAINTENANCE COSTS IN AN ECONOMIC ANALYSIS(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA R N CLARK DEC 87 1/2

UNCLASSIFIED F/G 15/5 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

DTIC FILE COPY

2

AD-A188 844

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

Standardization: Using Comparative Maintenance Costs in an Economic Analysis

by

Roger Nelson Clark

December 1987

Thesis Advisor: Dr. P. M. Carrick

Approved for public release; distribution is unlimited.

DTIC
ELECTE
FEB 1 2 1988
S D
E

88 2 09 115

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b. OFFICE SYMBOL (If applicable) 54	7a. NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c. ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000	7b. ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
STANDARDIZATION: USING COMPARATIVE MAINTENANCE COSTS IN AN ECONOMIC ANALYSIS

12. PERSONAL AUTHOR(S)
Clark, Roger Nelson

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Master's Thesis	FROM 1984 TO 1987	1987 December	104

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Standardization Diesel Engines

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This thesis investigates the use of comparative maintenance costs of functionally interchangeable equipments in similar U.S. Navy shipboard applications in an economic analysis of standardization. The economics of standardization, life-cycle costing, and the Navy 3-M System are discussed in general. An analysis of 3-M System maintenance costs for a selected equipment, diesel engines, is conducted. The potential sue of comparative maintenance costs in determining an equipment standard and equipment reprocurement is reviewed.

Approved for public release; distribution is unlimited.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Dr. D. M. Carrick	22b. TELEPHONE (Include Area Code) (408) 646-2536 22c. OFFICE SYMBOL 54Ca

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

U.S. Government Printing Office

Approved for public release; distribution is unlimited

Standardization: Using Comparative Maintenance Costs in an Economic Analysis

by

Roger Nelson Clark
Lieutenant Commander, Supply Corps, United States Navy
B.S., Idaho State University, 1975

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
December 1987

Author: ______________________
Roger Nelson Clark

Approved by: ______________________
P. M. Carrick, Thesis Advisor

____
L. Zambo, Second Reader

____
D. R. Whipple
Chairman, Department of Administrative Sciences

____
J. M. Fremgen
Acting Dean of Information and Policy Sciences

ABSTRACT

This thesis investigates the use of comparative maintenance costs of functionally interchangeable equipments in similar U.S. Navy shipboard applications in an economic analysis of standardization. The economics of standardization, life-cycle costing, and the Navy 3-M System are discussed in general. An analysis of 3-M System maintenance costs for a selected equipment, diesel engines, is conducted. The potential use of comparative maintenance costs in determining an equipment standard and equipment reprocurement is reviewed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

3-M	- Maintenance, Material, Management
AFP	- Adjusted Fleet Population
AILSIN	- Automated Integrated Language System Identification Number
APL	- Allowance Parts List
ASPR	- Armed Services Procurement Regulations
BHP	- Brake Horsepower
BOSS	- Buy Our Spares Smart
CCF	- Component Characteristic File
CFE	- Contractor Furnished Equipment
COSAL	- Coordinated Shipboard Allowance List
CSMP	- Current Ship's Maintenance Project
DOD	- Department of Defense
DSSP	- Defense Standardization and Specifications Program
FI	- Fuel Injection
FLEETPOP	- Fleet Population
HM&E	- Hull, Mechahical, and Electrical
HSC	- Hardware Systems Command
HSC	- Hierarchical Structure Code
ICP	- Inventory Control Point
ILS	- Integrated Logistics Support
ILSE	- Integrated Logistics Support Elements
IMA	- Intermediate Maintenance Activity
INSURV	- Board of Inspection and Survey

LAPL - Lead Allowance Parts List

LCC - Life-Cycle Cost

MDS - Maintenance Data System

MILSPEC - Military Specification

MSC - Military Sealift Command

NAMSO - Navy Material Support Office (now part of NAVSEALOGCEN)

NAVCOMPT - Comptroller of the Navy

NAVSEA - Naval Sea Systems Command

NAVSEALOGCEN - Naval Sea Systems Command Logistics Center (now includes command formerly known as NAMSO)

NAVSUP - Naval Supply Systems Command

NICN - Navy Item Control Number

NIH - National Institute of Health

NSN - National Stock Number

O&S - Operations and Support

OPNAV - Office of the Chief of Naval Operations

PMS - Planned Maintenance System

PTD - Provisioning Technical Documentation

R&S - Readiness and Supportability

RIC - Repairable Item Code

RPM - Revolutions Per Minute

SECAS - Ships' Equipment Configuration Accounting System

SF - Ship's Force

SHIPPOP - Ship's Population

SNAP - Shipboard Non-Tactical Automated Data Processing Program

SPCC - Ships Parts Control Center

SWAB - Ship's Work Authorization Boundary

TDBD - Top-Down-Breakdown

TYCOM - Type Commander

USCG - U.S. Coast Guard

WSF - Weapon Systems File

I. INTRODUCTION

A. BACKGROUND

The 1980's have witnessed unprecedented peacetime spending on conventional military hardware by the Department of Defense (DOD). Within the Navy, this spending has resulted in the acquisition of an assortment of ships and aircraft and increased emphasis on readiness and sustainability. The ambitious purpose of the current administration's increased Navy budget is to return to a 600 ship Navy, equip this force with the most technologically advanced weaponry available, and maintain it at the highest possible level of readiness.

This unprecedented level of military spending has brought with it a new era of intense Congressional oversight and rekindled the public controversy over defense versus domestic spending.

Much of the oversight and controversy surrounding defense spending has centered on military acquisition strategy and policy. The controversy is not only over <u>how much</u> is being spent for military hardware, but also, <u>how</u> it is being spent.

Navy procurement procedures used in the acquisition of major equipment and associated repair parts have received increased attention and criticism in recent years. Many problems have been identified in Navy procurement procedures, and a variety of initiatives have been implemented to correct them. A common criticism of Navy procurement procedures is that they are not cost effective, and that the Navy is not getting the maximum return on its procurement dollar.

Navy managers responsible for the procurement of equipment and repair parts are acutely aware of this criticism. In a broad sense, one initiative which appears to have great potential for reducing the total ownership costs of Navy equipment is standardization.

Standardization is defined as:

> ...the process by which the Department of Defense achieves the closest practicable cooperation among the services and Defense agencies for the most efficient use of research, development and production resources, and agrees to adopt on the broadest possible basis the use of:
>
> (a) common or comparable operational, administrative and logistical procedures
> (b) common or compatible technical procedures and criteria
> (c) common, compatible, or interchangeable supplies, components, weapons or equipment
> (d) common or compatible tactical doctrine with corresponding organizational compatibility. (DOD Dictionary, p. 245)

The idea of standardization is a ubiquitous cost saving strategy long recognized by DOD:

> Every individual, industry, and government agency sponsors or uses, to some degree, the standardization process. The basic purpose is essentially the same - to achieve the greatest practical uniformity of items, materials, and practices in order to minimize the costs and risks associated with developing, managing, using, and maintaining similar things satisfying similar functions. (DSSP, p. 3)

Within the Navy, Navy Sea Systems Command Logistics Center (NAVSEALOGCEN), Mechanicsburg, PA has been actively involved in standardization efforts for over 15 years. NAVSEALOGCEN is composed of logisticians who serve as a link between NAVSEA, the Hardware System Command (HSC) which procures major end items of Navy shipboard Hull, Mechanical, and Electrical (HM&E) equipment, and Navy Ships Parts Control Center (SPCC), the Inventory Control Point (ICP) which procures repair parts to support the end items of equipment. Currently, NAVSEALOGCEN's standardization efforts are concentrated in the following three areas:

1) Development and maintenance of data used to measure and direct improvements in the relative degree of standardization.
2) Development and maintenance of standardized data requirements.
3) Development of improved procurement practices designed to measure the effectiveness of standardization. (Jones, p. 1)

Efforts in the third area, measuring the effectiveness of standardization, are perhaps the least obvious, yet most important. As is common with standardization initiatives, it is easy to state the intrinsic benefits of standardization but difficult to quantify them in dollar terms. Standardization benefits are long term in nature and achieved through a judicious trade-off between acquisition costs and ownership costs. Acquisition costs, which are easily quantified, may be a trivial portion of total costs but can have a high "multiplier" effect on the basis for standardization initiatives. This puts a standardization advocate in a precarious position. To be successful, he must demonstrate the economic advantages of standardizing functionally interchangeable equipment prior to procurement, even though the full benefits of standardization will not accrue until long after initial procurement.

B. OBJECTIVES

Traditionally, the measurement of economic advantage for functionally interchangeable equipment has been based solely on the lowest acquisition price. Recent Navy emphasis on competition has continued to focus on acquisition price, although it is widely recognized that a more appropriate measure of total ownership costs would be complete life-cycle costs (LCC) including follow-on logistic support and maintenance costs. Unfortunately, reliable estimates of follow-on logistic support and maintenance costs are difficult, if not impossible, to obtain. Estimates which are available generally come from the equipment manufacturer, who can hardly be considered an unbiased source.

A NAVSEALOGCEN initiative is currently underway to determine valid estimates of an equipment's follow-on logistic support costs. This initiative is an attempt to demonstrate the economic advantage which could be obtained by standardizing functionally interchangeable equipment, thus reducing follow-on logistic support costs. This initiative is an example of the difficult process of quantifying, in dollar terms, the economic benefits which accrue from standardization.

Given that there may be significant economic advantages in standardizing functionally interchangeable equipment, a crucial question still remains--what equipment should be chosen as the standard? This question is also germane to what is known as "reprocurement", a process in which equipments identical to those already in the Navy inventory are procured for new applications. It seems logical that these choices should be based on equipment LCC and that maintenance cost should be a substantial component of total LCC. If comparative maintenance costs of functionally interchangeable equipment can be determined, they may play an important role in an economic analysis and justification of standardization.

The primary purpose of this thesis is to perform a post audit of instances in which different functionally interchangeable equipments were introduced into the Navy inventory for similar applications. This post audit is an attempt to determine if comparative maintenance costs of these equipments could be used in determining a least cost standard for that application. This thesis will make extensive use of NAVSEALOGCEN's standardization data base to determine functionally interchangeable equipment and the Navy's Maintenance, Material, Management (3-M) System to collect maintenance data.

C. RESEARCH QUESTION

The primary research in this thesis attempts to answer the question: Can maintenance costs of functionally interchangeable equipments in similar U.S. Navy shipboard applications be used in an economic analysis of standardization? As previously discussed in the Objectives section, this includes using comparative maintenance costs for the selection of a standard equipment on which to base an economic analysis of standardization or as the basis of a reprocurement decision. The research question in this thesis is a small facet of the economics of standardization, but is critically important because it could serve as the starting point of any analysis of functionally interchangeable equipments with U.S Navy applications.

Secondary questions addressed by research include:

1) Using available data, is it possible to readily determine "functionally interchangeable" equipment?
2) Is current, reliable, and comprehensive maintenance data available from the Navy 3M System?
3) Are maintenance costs of functionally interchangeable equipments significantly

different and do these costs represent a significant portion of total LCC?

4) Can historical maintenance cost data be used as a basis to estimate maintenance costs of similar equipment?

D. SCOPE AND LIMITATIONS OF RESEARCH

This thesis is limited to U.S. Navy HM&E equipment with shipboard applications which is under the cognizance of NAVSEALOGCEN. This equipment is generally procured to performance instead of design specifications. This creates the greatest potential for non-standardization of functionally interchangeable equipments. It is further limited to diesel engines which were chosen as a specific, representative HM&E equipment for the purpose of this thesis. Diesel engines were chosen because of their readily identifiable function, commercial availability, similarity of applications, and high fleet populations.

A research visit to NAVSEALOGCEN, Mechanicsburg, PA facilitated the collection of data and interviews with NAVSEALOGCEN standardization and 3M personnel.

E. ORGANIZATION

Chapter II is a discussion of the three interrelated topics which form the basis for this thesis: the economics of standardization, life-cycle costing, and the use of Navy 3-M data. Research for Chapter II was confined largely to Navy instructions, directives, and papers on the three topics. Chapter II provides a broad perspective from which to view the investigative framework described in Chapter III, and the data analysis in Chapter IV. Conclusions are presented in Chapter V.

II. USING COMPARATIVE MAINTENANCE COSTS IN AN ECONOMIC ANALYSIS OF STANDARDIZATION

The three topics of this chapter, the economics of standardization, life-cycle costing, and the 3-M System, set the stage for the remainder of this thesis.

The discussion on the economics of standardization provides the reader with insights into the costs and benefits of standardization. Life-cycle costing is described as the most appropriate method for comparing the cost of functionally interchangeable equipment. The Navy Ships' 3-M System, the source of maintenance data used in this thesis, is described in detail.

A. THE ECONOMICS OF STANDARDIZATION

Economics is the study of how individuals and society employ scarce resources with the objective of improving resource allocation through cost/benefit analysis. So, a discussion of the economics of standardization necessarily entails identifying its costs and benefits. Many of the benefits of standardization are difficult to measure in terms of the basic management yardstick--dollars and cents. The most significant monetary benefit of standardization is a negative cost; that is, the savings achieved by not allowing a situation of non-standardization to occur. The costs of standardization are nearly as difficult to describe. They include the up-front trade-off between buying something that apparently costs more, but will cost less in the long run because of lower support costs due to standardization, and the cost of collecting the data necessary to develop and maintain standards.

1. Benefits of Standardization

Although they may be difficult to quantify, intuitively it is obvious that many benefits accrue from standardization. In one of the very few texts on the subject, The Economics of Standardization, Robert B. Toth gives a generalized list of benefits:

> By minimizing the variety of items, processes, and practices, standardization:
> -Improves efficiency in design, development, material acquisition
> -Conserves money, manpower, time, facilities, natural resources
> -Enhances interchangeability, reliability, safety, maintainability. (Toth, p. 17)

Further, Toth breaks standardization benefits into two categories--"tangible" and "intangible". He defines tangible benefits as those which can be measured or counted. Tangible benefits include such things as:

-Greater discounts from larger orders
-Reducing time required for design
-Processing fewer purchase orders
-Reducing warehouse operating costs
-Reducing capital investment
-Decreasing stocks of spare parts (Toth, p. 17)

Intangible benefits include:

-Reducing hazard of technical errors of judgment

-Reducing the need for minor supervisory decisions
-Providing a common language between buyers and sellers
-Improving quality control based on accepted and explicit specifications
-Improving user and customer confidence (Toth, p. 18).

DOD stresses the tangible benefits of standardization.

> The Defense Standardization and Specification Program (DSSP)...was established in 1952 to improve the operational readiness and cost effectiveness of defense material by promoting the development and use of common systems, subsystems, equipment, components, parts, materials, engineering practices, and technical data (DSSP, p. 9).

The most recent DSSP overview lists the primary purposes for applying standardization principles (i.e., benefits as:

-Standardization <u>reduces</u> the <u>unnecessary and inefficient proliferation</u> of generally similar types, kinds, sizes, and styles of items. Where an existing product or service can adequately do the job, it should be used rather than creating a new one. A decision to standardize on an existing product saves money, manpower, and time. When a single product (standard item) can perform the job of several other products, replacement of the other products should be considered. Where a new product may potentially have multiple applications, the broad use of this product should be explored.
-Standardization of parts, components and subassemblies <u>reduces</u> the <u>risks</u> associated with developing and producing new products and services. Standardized products have a track record of usefulness, quality, reliability, maintainability and performance. The suitability of a standard product or service to meet requirements can be based on actual experience rather than theory or promises.
-If properly accomplished, standardization <u>provides</u> a

stepping stone for evolutionary improvements. It promotes technological growth by providing a solid foundation for innovation. Modifications to existing standardized products may make them acceptable for future applications, and, when a superior product or technology is developed, this may be used as the basis for a new standard.

-Standardization conserves resources by minimizing and simplifying training, technical data, engineering and support requirements. Use of standard items should significantly reduce expenditure of research, development, test and evaluation, and logistics support resources. New items which enter a supply system may need to be tested. Often, these new items bring with them the need for special support equipment and repair/spare parts which remain in the supply system for the life of the new end product. Standardization reduces the total logistics burden. (DSSP, p. 3)

Narrowing the focus of benefits to U.S. Navy HM&E equipments provides the opportunity to discuss the economics of standardization within the context of this thesis. NAVSEALOGCEN summarizes the more significant benefits to be achieved through an effective standardization program for HM&E equipments as:

-Standardization results in larger populations of identical equipments with resultant savings from larger production procurements.

-Improved Fleet readiness through a better and deeper supply of fewer items. Replenishment procurements and shipboard allowances are directly proportional to equipment parts populations.

-Improved quality of training resulting from a decrease in training variations.

-Substantial savings resulting from reduced provisioning requirements, inventory management costs, and other Integrated Logistics Support (ILS) costs resulting from the proliferation of equipment designs for similar applications requirements.

-Improvement in the BREAKOUT [competitive acquisition of formerly sole-source items] and BOSS [Buy Our Spares Smart] Programs by reduction of the items to be considered and by increased competitiveness associated with larger procurements. [Given contractor discounts for larger procurements]

-The inherent benefit of improved equipment design and reliability. (Jones)

2. Costs of Standardization

A discussion of the economics of standardization necessarily includes identifying standardization costs. Toth segregates standardization costs into two types of costs--fixed and variable. Fixed costs are incurred as long as a standards operation is functioning. Fixed costs include:

-Purchasing and maintaining a library of standards.
-Participating in national and international standardization activities.
-Training for the standards department staff.
-Providing a general advisory service on standards and related subjects.
-Time spent by the standards department training personnel within the company or agency in standardization and related subjects.
-Supervision. (Toth, p. 14)

Variable costs are directly related to the number of standardization projects. Variable costs include:

-Investment costs--those expenditures associated with standards development and the effort to make potential users aware of a new standard to encourage its use.
-Implementation costs--engineering change documents, reloading, changing stock numbers on repair parts, scrapping obsolete stock.
-Revision costs--whenever a standard is corrected or updated.
-Running costs--time spent interpreting details of a particular standard or advising on applications.
(Toth, p. 15)

These costs of standardization are not as intuitively obvious as the benefits. One apparent cost of standardization, particularly within the context of this thesis, is the higher procurement cost of a standard equipment as determined by competition of procurement price. The accuracy of this cost is a central theme of this thesis and will be discussed in detail in upcoming chapters.

3. Applications of Standardization Principles

To achieve the greatest benefits from standardization initiatives requires a system where a situation of non-standardization (for whatever reasons) has been permitted to proliferate. Data from a NAVSEALOGCEN study, indicates that programmed standardization for Navy HM&E equipment is almost non-existent.

> Standardization, especially in the area of HM&E equipments, represents an unbelievable potential for improvement in both economic considerations and Fleet readiness. A recent study conducted by NAVSEALOGCEN indicates that the Navy introduces over 8,000 new HM&E equipment designs to the Fleet each year. The total number of HM&E equipment designs currently installed and maintained by the Navy is in the order of magnitude of 200,000, which represents a capital investment in excess of $15 billion. From this perspective, HM&E equipment compositely represents a potentially fruitful area for substantial benefit to the Navy through standardization. To [emphasize] the potential, our data indicates that approximately 50 percent (or over 100,000 designs) of all HM&E equipment designs currently used by the Navy have Fleet populations of five or less...Even with larger classes of ships, over 50 percent of all HM&E equipment designs have commonality to only one or two ships. From an economic viewpoint as well as a logistics support perspective, this apparent lack of standardization is absurd. (Jones, p. 2)

This apparent lack of standardization for HM&E equipment is caused by many factors and competing demands including:

-Most HM&E equipments are Contractor Furnished Equipment (CFE), where the shipbuilder or repair activity is profit motivated.
-The use of performance procurement specifications vice design central specifications.
-Lack of appropriate techniques to objectively measure the benefits of standardization.
-Lack of objective techniques to define standardization potential and to direct/focus standardization
-Underutilization of available data, etc.
-Ineffective incentive programs to encourage standardization. (Jones, p. 3)

Although it is difficult to pinpoint all the reasons for a lack of standardization among Navy shipboard HM&E equipment, the common thread of the factors listed above is an inability to demonstrate the economic advantages of standardization. A condition of non-standardization apparently occurs by default as other, more identifiable, economic concerns are satisfied.

Management decisions are economic decisions. To make the correct decision, all economic factors must be considered. This section discussed the economics of standardization, including its costs and benefits and the apparent lack of standardization, among Navy shipboard HM&E equipments from a management perspective. The intent of this section was to demonstrate that, although there may be many benefits achieved with standardization and standardization benefits may outweigh its costs, it is difficult to prove because of the lack of an analytical framework. The primary research in this thesis is an attempt to contribute to an analytical framework when investigating the economics of standardizing Navy shipboard HM&E equipment.

B. LIFE-CYCLE COST

The total ownership cost, or life-cycle cost (LCC) of an equipment is a key ingredient in an economic analysis of standardization. The benefits of standardization accrue through the reduction of costs associated with supporting like equipments. This section provides the reader with the current DOD and Navy policy on the use of LCC and discusses LCC components. The information in this section is intended to explain the logic of life-cycle costs of which maintenance costs are a component, and contrast LCC with procurement costs.

1. Definition of LCC

Life-cycle cost is defined as:

> the sum total of the direct, indirect, recurring, non-recurring and other related costs incurred, or estimated to be incurred, in the design, development, production, operation, maintenance and support of a major system over its anticipated life span (OMB Circular, A-109).

Stated in another way, focusing on specific equipments, LCC is an economic assessment of alternative equipment, considering all significant costs of ownership over the equipment's economic life expressed in equivalent dollars.

The concept and logic of LCC is readily understandable. In practice, it is often difficult to determine or estimate all ownership costs. This difficulty tends to limit the use of LCC within DOD and the Navy, even in those cases where it is the most appropriate costing technique.

2. DOD and Navy LCC Policy

DOD has long recognized the benefits which can be achieved by the use of LCC and has been aware that application of LCC principles was inconsistent:

> The Department of Defense has become increasingly concerned over the military, technical and economic consequences of the practice of introducing new equipments without proper evaluation of the total costs over the life-cycle of the equipment. As a result, DOD has developed the LCC (Life Cycle Costing) program. LCC is a technique of minimizing life cycle cost by considering the cost of as many logistics elements as possible during the acquisition process. Material contracts which include logistics elements in the bidding evaluation criteria will prevent some of the logistics problems associated with less costly inferior products. In many instances, LCC techniques can lead to significant product improvement at a nominal price increase. (NAVSUPINST 4000.32, p. A-1)

The logic behind the LCC program was clearly stated:

> The costs to operate, maintain and support most equipments or systems over their life cycle are generally far greater than the initial investment. Therefore, each of the total spectrum of identifiable costs to support and to maintain equipments should be separately evaluated and traded off against all other identifiable costs to determine the most cost-effective combination of the major identifiable factors; e.g., corrective and preventive maintenance, training, inventory management, inspection, installation, check-out, transportation and documentation. (NAVSUPINST 4000.32, p. A-1)

A common complaint in the Navy is that LCC is not a usable costing technique in choosing between equipment alternatives because equipment must be purchased competitively based on procurement price. This complaint is without grounds--ample legal basis exists to compete LCC:

> Life-cycle costing is a technique by which we seek the lowest total cost of government ownership in our acquisitions. The legal basis for this method of procurement is found in Title 10 of the United States Code, Section 2305(c) which states that "Award shall be made...to the responsible bidder whose bid...will be most advantageous to the United States, price and other factors considered." This requirement is expressed in the Armed Services Procurement Regulations (ASPR) 3-801 as "It is the policy of the Department of Defense to procure supplies and services from responsible sources at fair and reasonable prices calculated to result in the lowest ultimate overall cost to the Government." (NAVSUPINST 4000.31, p. D-1)

3. <u>Components of LCC</u>

Having explained the concept of LCC, it is now time to look at the specific components of an equipment's LCC. An equipment's LCC could be viewed as the sum of procurement cost plus all operating and logistic support costs. Integrated Logistic Support Elements (ILSE) are specified in DODINST 5000.39 as:

- Maintenance
- Manpower and Personnel
- Supply Support
- Support Equipment
- Technical Data
- Training and Training Support
- Computer Resources Support
- Facilities
- Packaging, Handling, Storage, and Transportation
- Design Interface (ILS, p. 1-3,5).

Research has indicated that procurement costs account for less than half the LCC of a weapon system. In fact:

> ...R&S [readiness and supportability] objectives are links to the determination of LCC and particularly operational and support (O&S) costs which generally account for about 60 percent of the total system LCC. (ILS, p. 1-2)

In this thesis, "maintenance costs", composed of man-hours expended on maintenance and parts used at the organizational and intermediate maintenance levels, will be used to calculate comparative maintenance costs for functionally interchangeable equipment. This maintenance cost includes a significant portion of the differentiable ILSE previously listed, and thus serves as a basis for a comparative equipment LCC. Chapter V will discuss the applicability of using this maintenance cost in an economic analysis of standardization.

C. THE NAVY SHIPS' 3-M SYSTEM

Maintenance data used in this thesis was obtained entirely from the Navy Ships' 3-M System. The following description of the 3-M System is provided to help the reader understand what the 3-M System is and how it works.

1. History

In January 1963, the Office of Naval Research tasked George Washington University with developing a system to manage maintenance for increasingly complex

Naval weapons. To be effective, it was recognized the system needed to include:

- Standardization--uniformity of maintenance standards and criteria.
- Efficiency--effective use of manpower and material resources.
- Documentation--recording of maintenance and maintenance support actions to establish a material history.
- Analysis--aid in improvement of maintainability, reliability, and cost reduction.
- Configuration Control--a means of reporting and recording changes in what equipment is installed onboard ships. (3-M Manual, p. 2-2)

To meet these needs, the Ships' 3-M System was introduced in 1965.

2. Purpose and Description

The Ships' 3-M System is a management tool designed to provide efficient, uniform methods of conducting and recording preventive and corrective maintenance in a way which allows fast and easy access to the collected data. Preventive maintenance includes actions taken to prevent equipment from failing, such as changing the oil, cleaning filters, calibrating, etc. Corrective maintenance includes actions taken to fix equipment which has failed or is not working as well as it should. (3-M Manual, p. 2-2)

The 3-M System consists of two separate systems:

- PMS (Planned Maintenance System)-concerned with preventive maintenance
- MDS (Maintenance Data System)-concerned with the collection of corrective maintenance and configuration data. (3-M Manual, p. 2-2)

PMS is a standardized method of documenting, planning, and scheduling shipboard preventive maintenance. Since this thesis uses historical data collected by MDS, the remainder of this discussion will focus on the MDS of the Ships' 3-M System.

MDS is a system for the collection of data concerning corrective maintenance and configuration changes. The data collected includes: (1) man-hours expended by rate, (2) parts usage,and (3) a brief description of the problem and (4) the maintenance required or performed. Submarines report all maintenance and configuration change actions. Surface ships are required to report only the four types of actions above. (3-M Manual, p. 2-4)

The data collected by MDS is used for several purposes:

- CSMP (Current Ships Maintenance Project)-a computer printout which lists deferred maintenance actions.
- Automated PREINSURV (Pre-Inspection and Survey)-a list of deficiencies
- Automated Work Requests-for repair facility use.
- Configuration Control-for ships to report changes to the configuration of equipments.
- Automated Reports-for analysis. (3-M Manual, p. 2-5)

3. <u>Source and Input</u>

The source of Ships' 3-M data is all ships, submarines, and activities to which the Ships' 3-M System applies. Some ships and activities have computerized maintenance management systems onboard and provide their Ships' 3-M Data in tape format. The Shipboard Non-Tactical Automated Data Processing Program (SNAP) is a two-part program designed to modernize and expand the Navy's automated data processing capabilities afloat. SNAP I replaces the present computers onboard some larger ships. SNAP II provides smaller ships and submarines with their own computer capability. Ships and activities without computerized maintenance management systems onboard report 3-M data using handwritten forms. (3-M Manual, p. 3-2)

Five forms (hard copy or automated) are used to report data to MDS. They are:

- 2K (OPNAV 4790/2K, SHIPS MAINTENANCE ACTION FORM) is used to report:
    - deferred maintenance actions and their completion
    - completion of corrective maintenance actions.
- CK (OPNAV 4790/CK, SHIPS CONFIGURATION CHANGE FORM) is used to report:
    - addition or installation of any new equipment
    - removal of any installed equipment
    - replacement or exchange or any equipment
    - modification of any installed equipment
    - relocation of any equipment
    - accomplishment of any alteration directive.
- 1250 (NAVSUP Form 1250, INTERNAL SHIP SUPPLY ISSUE DOCUMENT) is used to requisition and report parts needed to complete a maintenance action by units without a computer-aided Supply Management System.
- 1348 (DD Form 1348, DOD SINGLE LINE SUPPLY ISSUE DOCUMENT) is used to requisition and report parts needed to complete a maintenance action by

units without a computer-aided Supply Management System.
- 2F (OPNAV 2790/2F, IMA WORK PROGRESS CARD) is used to report job status and man-hours in the Intermediate Maintenance Systems (IMMS). Intermediate Maintenance is maintenance performed by tenders and Ship's Intermediate Maintenance Activities (SIMA). (3-M Manual, pp. 3-2,3)

4. Central Data Bank

Ships' 3-M data is stored in a central data bank maintained by NAVSEALOGCEN in Mechanicsburg, PA. The central data bank consists of computer files of data provided by the 2Ks, CKs, 1250s, 1348s, and 2Fs submitted by ships. Reports drawn from this central data bank are provided to users. Figure 2.1 is a diagram of the Ships' 3-M System data flow.

5. 3-M TYCOM System

NAVSEALOGCEN has been the Navy's central repository for 3-M data and has provided 3-M data and products to users since the mid-1960's. Although it had long been recognized that the magnetic tape files and batch processing used by NAVSEALOGCEN were too slow and could not provide 3-M data tailored to specific user needs, little could be done because of computer saturation at SPCC. NAVSEALOGCEN is co-located with SPCC and uses SPCC computers for data processing. In 1985, the 3-M TYCOM Terminal System was developed to solve the long-standing problems previously cited. This system uses data processing facilities at the National Institute of Health

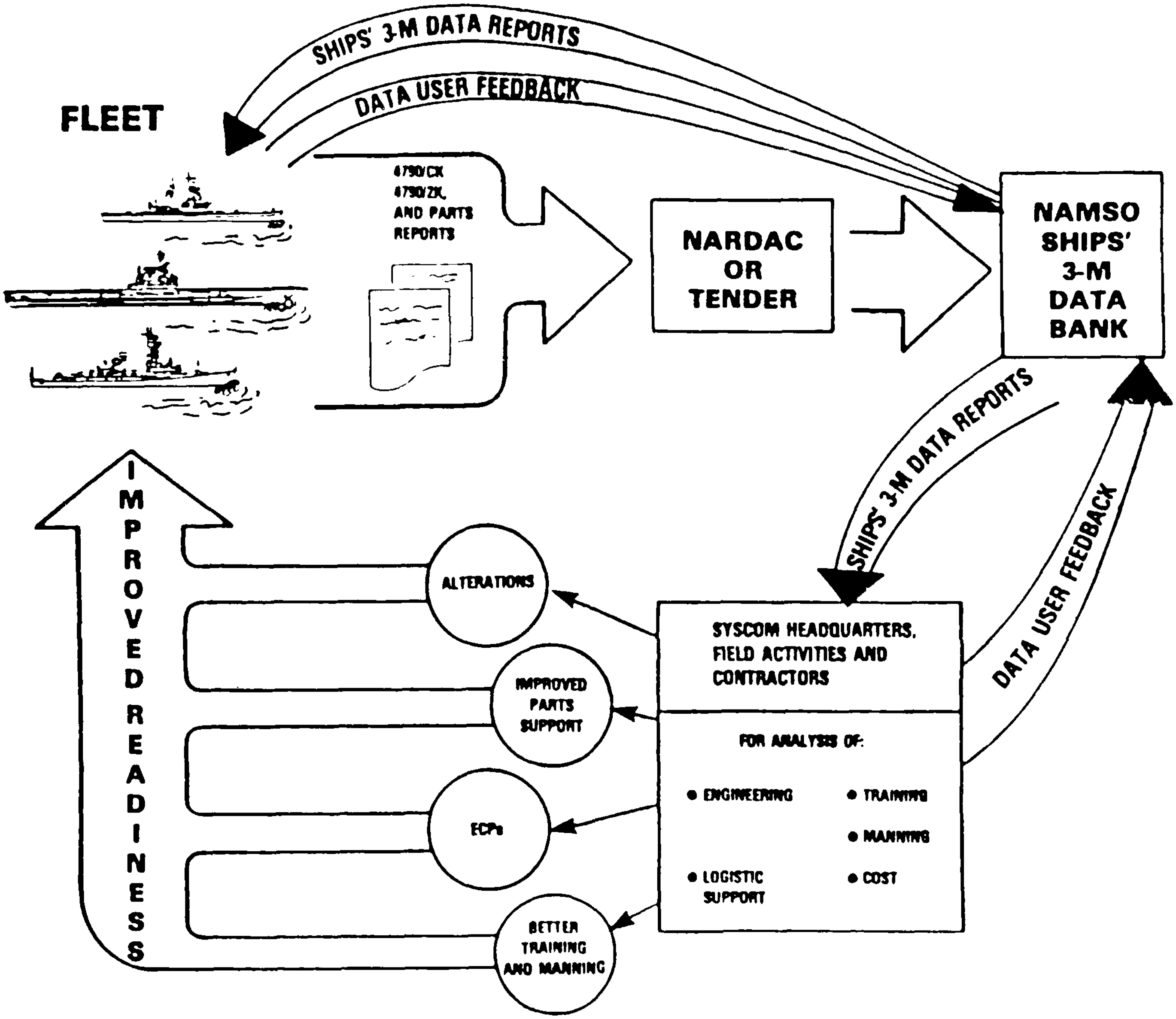


Figure 2.1

SHIPS' 3-M DATA SYSTEM FLOW

(NIH) in Bethesda, MD. The 3-M TYCOM Terminal System provides the user with a capability to request specific data reports and other products generated from the 3-M data base; the means to obtain reports at a user's terminal facility; and access to an ad-hoc query system which uses an abridged data set derived from the 3-M master files. (3-M TTS Manual, para 1.3) This system has vast potential to expand the use of 3-M data. All 3-M data used in this thesis were obtained from the 3-M TYCOM Terminal System.

D. SUMMARY

The three topics of Chapter II were intended to provide a broad perspective from which to understand the purpose of this thesis--determining if it is feasible to use comparative maintenance costs of functionally interchangeable equipment in an economic analysis of standardization.

The section on the economics of standardization demonstrated that, given the data necessary, it may be possible to perform a cost/benefit analysis of standardization. As is usually the case, the major stumbling block is identifying all of the costs and benefits. The inability to demonstrate the significant economic advantages of standardization has apparently permitted other economic considerations to prevail and resulted in the proliferation of non-standardization of Navy Shipboard HM&E equipments.

The section on LCC indicated that LCC is the appropriate costing technique to compare functionally interchangeable equipment and that maintenance costs are thought to be a significant component of LCC. Finally, the section on the Navy Ships' 3-M System described a ready source of comprehensive maintenance data for all shipboard equipment.

It should now be evident that the economics of standardization is a complex subject. The purpose of this thesis is not to answer all of the questions surrounding the economics of standardizing interchangeable HM&E equipment in Navy ships. Rather, its purpose is to investigate what could well be the starting point of an economic analysis of standardization-choosing the equipment standard. Since all of the benefits of standardization can be demonstrated only through an analysis of savings achieved by reduced support costs of a standard equipment, to perform a correct analysis it is essential to select that equipment with the lowest support costs as the standard.

The following chapters attempt to determine if it is feasible to select a standard equipment with the lowest LCC by using comparative maintenance costs of functionally interchangeable equipment as an indication of relative life-cycle costs for these equipments.

III. INVESTIGATIVE FRAMEWORK

This section will describe the investigative framework used to analyze the competitive maintenance costs of functionally interchangeable equipment. It includes background to familiarize the reader with the investigative process and descriptive terminology, and a step-by-step explanation of the methodology used.

A. BACKGROUND

To fulfill its intended purpose, the investigative framework must allow for the accomplishment of two main objectives:

1) A determination of what equipments are functionally interchangeable
2) A determination of the maintenance costs of each functionally interchangeable equipment.

As this section develops, the reader will come to appreciate that accomplishing the first objective is a very complex and difficult matter, and that this difficulty is very likely a contributing factor to the apparent lack of standardization among Navy HM&E equipments. However, once functionally interchangeable equipment can be identified, determining their comparative maintenance costs is a simpler process.

1. Equipment Identification

Prior to discussing the methodology used in this thesis, it is necessary to understand the process the Navy uses to discretely identify and maintain an inventory of shipboard equipments. This process is at the heart of the standardization issue, because standardization requires an application inventory description that includes form, fit, and function characteristics. In other words, it is impossible to consider various equipments, including a standard, for a specific application unless the form, fit, and function characteristics of that specific application are known. The only way to know the characteristics of a specific application is to record (and have available) the characteristics of the equipment currently filling that specific application.

a. Component Characteristic File

The SPCC Component Characteristic File (CCF) is an accumulation of equipment identification and form, fit, and function characteristics data assembled during the provisioning process for Navy equipment (Jones, p. 6). Provisioning is the process of determining the range and depth of spare parts for an equipment. It will be discussed in greater detail later in this section. During the provisioning process, a CCF pattern is selected by the provisioner and applicable characteristic data from the equipments' Provisioning Technical Documentation (PTD) is input to the CCF. PTD is a generic term for the various types of provisioning lists and information used to describe parts or equipment including specifications, standards, drawings, photographs, sketches and descriptions, assembly and general arrangement drawings, schematic diagrams, and wiring and cabling diagrams (DODINST 4151.7). This process creates a data base containing equipment and the equipment's form, fit, and function characteristics. The CCF is an adjunct to SPCC's Weapons Systems File (WSF), the Navy's central equipment data repository. One of the uses of the CCF is to provide the descriptive source header data on Navy Allowance Parts Lists (APL's) which will also be discussed in greater detail later in this section.

Although the CCF has the potential to be a useful standardization tool, its usefulness has been limited due to substantial differences in the selection of appropriate CCF patterns and inconsistent and incomplete PTD input. In 1984, NAVSEALOGCEN initiated a program to improve the quality and utility of CCF data. Its objectives were:

(1) To establish a specific correlation between CCF pattern and equipment category. This was accomplished by reducing the number of patterns and developing a one to one relationship with existing Lead Allowance Parts Lists (LAPL), which are the primary HM&E provisioning guidance documents.

(2) The development of a set of characteristics data elements for each pattern which accurately identifies the form, fit, and function requirements for the equipment being provisioned. This effort has been accomplished with developed patterns approved by NAVSEA.
(3) The development of detailed data input specifications which will standardize data records and establish the capability to [automate] CCF data.
(4) To require the acquisition of all applicable CCF data as part of the PTD acquisition. (Jones)

The result of this initiative is an improved file known as the "Modernized" CCF. The CCF is an extremely large file. It takes 28 reels of magnetic tape to hold the characteristics data for the 200,000 equipments now included in the CCF. (Jones) Equipment form, fit, and function characteristics which will be used to determine equipment interchangeability in this thesis were obtained from the Modernized CCF.

b. Allowance Parts List

At this time, it is necessary to have a more complete understanding of two previously introduced terms:

- Lead Allowance Parts List
- Allowance Parts List.

The LAPL is a "pattern" used by the provisioner to determine maintenance significant (estimated to fail during normal usage) parts during the provisioning process:

> For Hull, Mechanical, and Electrical (HM&E) equipments, the LAPL method reflects the requirements of a shipboard equipment maintenance plan and is used in the preparation of APLs. The LAPL will list those types of items determined to be maintenance significant, e.g., the LAPL for a centrifugal pump will show

> that all shims, seats, sleeves, etc., are considered to be maintenance significant and are to be listed on the APL. The maintenance level code, repair capability code and recoverability code, among others, will be provided for each item. Manufacturers drawings, operating manuals, etc., are used with the LAPL to identify specific parts and develop the APL. (COSAL, p. 1-3)

Each LAPL has an identifying number. The LAPL number can be used to make the "first cut" at identifying functionally interchangeable equipment. It serves to identify a broad category of similar equipment with the same maintenance philosophy.

As its name implies, the APL is the list of maintenance significant piece parts which make up an equipment. But, because it also contains the descriptive header data previously mentioned, the APL number is also used to discretely identify an equipment. To understand how the APL has become the Navy's equipment identifier, it is necessary to briefly discuss the provisioning process.

As new equipments are introduced into the Navy inventory, PTD, consisting of the equipments' technical characteristics, is submitted to SPCC. PTD is used by the provisioner to build an APL to provide initial supply support for the equipment. As a first step, the equipment's characteristics are "matched" against existing equipments and if determined to be unique (a new equipment), a new Repairable Item Code (RIC) is assigned to that equipment. As the provisioning process is completed by adding logistics and technical information to the new RIC assigned (i.e., "building" the APL), the RIC becomes an APL number. The number itself does not change, its name changes when the provisioning process is completed. Because of the process just described, each different APL comes to identify a unique, discrete equipment. The process of building an APL is complex and labor intensive. There is currently an HM&E equipment provisioning backlog at SPCC of one to one and one-half years. Once the process starts, it can still require several years to complete depending primarily on the quality and completeness of PTD. (Jones)

It has long been recognized that the APL is not an ideal equipment identifier, a purpose for which it was never really intended. One of the APL's biggest shortcomings as an equipment identifier is that it "cuts across" the ships configuration at one specific, although broad, level. This level is composed only of equipments determined to be maintenance worthy by the provisioner and thus, require an APL. The ideal equipment identifier would represent a comprehensive "top-down-breakdown" (TDBD) of the entire ship. Numerous TDBD schemes have been investigated which would provide a coded hierarchical structure of the entire ship. The Equipment Identification Code (EIC) is an example of one of the Navy's first attempts to implement a TDBD structure code, but its usefulness is limited due to a lack of comprehensiveness. It now appears that the APL and EIC will eventually be replaced by something similar to the Automated Integrated Language System Identification Number (AILSIN) as the Navy's equipment configuration identifier. AILSIN is:

> A twelve digit coding system developed by SECAS [Ships' Equipment Configuration Accounting System] to identify shipboard functions to a manageable level. The AILSIN employs the SWAB (Ship Work Authorization Boundary) as the underlying foundation and further coding and grouping of equipment described in a SWAB. In addition the AILSIN includes a two character code that provides a reference to a generic description of an equipment or component serving a particular function. (COSAL, p. 3-17)

A hierarchical structure code such as AILSIN has significant standardization implications. AILSINs make it easier to identify functionally interchangeable equipments by providing a complete picture of the interrelated form, fit, and function characteristics. However, at this point in time, the process of AILSIN coding is not nearly complete, and for all its shortcomings, the APL remains the Navy's discrete equipment identifier. This thesis will attempt to collect 3-M System maintenance costs for unique functionally interchangeable equipments identified as having different APL's.

2. Summary

The purpose of this section was to provide the reader the background to understand how functionally interchangeable equipment will be identified. It should now be apparent that there is currently no hierarchical coding system to readily identify equipment form, fit, and function characteristics and determine functional interchangeability. Rather, functional interchangeability must be determined by comparing the CCF characteristics of different APL's within a LAPL category.

The next section will provide the step-by-step methodology used to accomplish this comparison process, and the process of collecting and comparing 3-M System maintenance costs.

B. METHODOLOGY

This section will describe the methodology used to determine comparative maintenance costs of functionally interchangeable Navy shipboard HM&E equipment. It consists of three basic steps:

1) Determine candidate functionally interchangeable equipments

2) Collect maintenance data for these equipments and determine the costs associated with maintenance

3) Adjust costs based on equipment fleet population to permit comparison.

Each of these three steps will now be explained in detail.

1. <u>Determine candidate functionally interchangeable equipments</u>

Since the purposes of this thesis are to propose a plausible methodology for and attempt to determine if it is workable, the scope of HM&E equipments were reduced to a manageable size. One representative HM&E equipment, diesel engines, was chosen for analysis.

Diesel engines have numerous applications in the U.S. Navy. On active U.S. ships they are primarily used for main propulsion (on some smaller ships), auxiliary electrical generators, and in small boats assigned to the ship (Captain's Gig, motor whaleboats). The specific applications of the diesel engines chosen for analysis in this thesis will be discussed in Chapter IV.

The first step in identifying potential functionally interchangeable diesel engines was to select one readily identifiable functional characteristic which would indicate interchangeability. The one chosen was Brake Horsepower (BHP). BHP is the:

> ...rated HP output, unless otherwise specified in the contract or order, [corresponding] to full-power operation of the ship, or its equipment under ship trial conditions (MILSPEC, p. A-4).

A report was then obtained from the CCF and NAVSEALOGCEN's Equipment File of U.S. Navy diesel engines with current fleet applications in LAPL Number/BHP sequence. It included the following data elements:

APL	The Allowance Parts List Number for the equipment
NOMENCLATURE	A description of the equipment
SHIPPOP	The number of ships the equipment is installed on
FLEETPOP	The total number of the equipment installed in the fleet
LINE	The Modernized Component Characteristic File (CCF) line number
CHARACTERISTIC	The Modernized CCF characteristic
CHARACTERISTIC LINE DATA	The Modernized CCF data for each characteristic

This report showed the commonality of the BHP characteristic within a given LAPL number. Its purpose was to provide APL's with the same (or similar) BHP within a LAPL category. Diesel engines with the same BHP within a LAPL can be considered as potentially functionally interchangeable.

A phone conversation with CDR Al Brown, NAVSEA (56X3B) Internal Combusion Life Cycle Manager, indicated that the BHP of diesel engines are considered "within a range" when preparing acquisition specifications. Therefore, diesels with similar, but not necessarily identical, BHPs would also potentially be functionally interchangeable.

The CCF report was analyzed to identify a group of APL's within a LAPL with similar BHP. There are eleven different LAPL's used to provision diesel engines.

Within LAPL 66-005, which is defined as:

> Engine - Diesel; 2 and 4 cycle, boat landing craft propulsion and auxiliary service engines (except vertically opposed piston configuration). Mobile engines, portable engines, emergency service engines (CCF Report),

twenty-three unique APL's were identified within a range of 225-300 BHP. These twenty-three APL's were then further analyzed by comparing the following additional form, fit, and function characteristics:

RPM	Revolutions per minute when operating at BHP
Cycle	The number of piston strokes in a power cycle
Cylinder	The number of piston cylinders
Bore	The diameter of the engine's cylinder
Stroke	Distance of piston travel from one extreme to the other during a revolution
Fuel Injection	Method of injecting the desired quantity of fuel into the combustion chamber (Diesel engines are classified into two types--"solid" or "air injection".) (McGraw-Hill Encyclopedia of Engineering, p. 238)

This process resulted in a determination that the twenty APL's displayed in Appendix A, representing a SHIPPOP of 430 and a FLEETPOP of 878 could be considered functionally interchangeable for the purpose of this analysis.

These twenty APL's will serve as the basis of the discussion in Chapters IV and V.

2. <u>Collect maintenance data for these equipments and determine the costs associated with maintenance.</u>

Once a family of APL's has been identified which represent a group of functionally interchangeable equipment, maintenance data was obtained from the 3-M TYCOM System for each APL.

To facilitate data collection, the analysis was limited to the previous three years of historical data.

This was necessary because the 3-M TYCOM System has a rapid retrieval capability for only the last three years of maintenance data which is maintained "on line". Data older than three years is purged to a magnetic tape file. Although this older data is available, the time and effort required to retrieve it limited its usefulness in this analysis. Maintenance data used in this thesis was retrieved from The 3-M TYCOM System on 20 October 1987 and includes maintenance actions dated 1 January 1984 to 31 August 1987, a period of three years and eight months (or 44 months). Considering the difficulties that would be encountered attempting to obtain pre-1984 data, the 1984-1987 "snapshot" of maintenance data is considered sufficient for the analysis conducted in this thesis.

The following 3-M TYCOM System data elements were chosen for this analysis:

DATA ELEMENT	DESCRIPTION
SHIP-TYPE	Ship Class (i.e. FFG)
HULL-NR	Ship's hull number
Noun-Name	Name of the equipment
SF-MHRS	Ship's Force Man Hours. The sum of man-hours reported by the organizational level maintenance activity
IMA-MHRS	Intermediate Maintenance Activity (IMA) Man Hours. Sum of the maintenance hours reported by the IMA
PARTS-COST	The sum of (quantity x unit price) of each item reported on DD Form 1348 and NAVSUP Form 1250 for each maintenance action

IMA-P-CST	IMA Parts Cost. The sum of parts cost only for those items with the second character of the Fund Code equal to "G", "H", or "I" (IMA Fund Codes)
DAYS-DOWN	Estimated number of days an equipment was down for maintenance calculated as follows: Completed Action--one day Parts Only Action--one day Deferrals--the number of days from the action date to the completion date. In the event of an uncompleted deferral, the days are counted from the action date to the day the data base was created.

(TYCOM 3-M Manual, p. 7.2)

Using these data elements, maintenance costs for each APL in Appendix C for the period 1 January 1984 to 31 August 1987 were calculated as follows:

Sum of SF-MHRS x $13.55[1]	= Ships Force personnel costs
Sum of IMA-MHRS x $16.40[2]	= IMA personnel costs
Sum of PARTS-COST	= Organizational maintenance level parts cost
Sum of IMA-P-CST	= IMA parts cost

Ships Force personnel costs
\+ IMA personnel costs
\+ Organizational maintenance level parts cost
\+ IMA parts cost
= Total maintenance costs

[1]Composite standard military pay rate for Navy Petty Officer Second Class (E-5)
[2]Composite standard military pay rate for Navy Petty Officer First Class (E-6)

Composite standard military pay rates are rates established by the Comptroller of the Navy (NAVCOMPT) for instances "where billing for military personnel services is appropriate" (NAVCOMPTNOTE 7041, p. 1). The rates were chosen to represent the grade of Navy personnel (on the average) responsible for performing maintenance at the shipboard and IMA maintenance levels based on the author's personal experience.

One qualitative data element, DAYS-DOWN, was also collected for this analysis. Although it may not be possible to calculate a cost associated with this data element, its direct link as an indication of equipment reliability may be important in a comparison of maintenance cost.

The resultant maintenance costs are displayed in Appendix C. They form the basis for the maintenance cost comparison discussed in Chapter IV.

3. Adjust costs based on equipment fleet population to permit comparison.

The process described so far has resulted in a family of APL's representing a group of functionally interchangeable equipment and the sum of maintenance costs over a period of forty-four months, associated with each equipment.

To permit comparison, it is necessary to adjust the total maintenance costs based on the fleet population of each equipment included in the analysis. Since the NAVSEALOGCEN Equipment File FLEETPOP is a cumulative total (i.e. the fleet population when the report was generated), a time-weighted average FLEETPOP was calculated as follows:

$$\frac{\text{SHIP in-service months during analysis period}}{\text{Total months in analysis period (44)}}$$

x Number of equipments included in analysis installed on ship

= Ship time weighted equipment population

Total of ship time-weighted equipment population = Adjusted FLEETPOP (AFP)

To calculate AFP required determining each APL's specific ship applications and then determining each ship's in-service period. The in-service period was determined by checking the commissioning date of each ship with one or more of the equipments included in the analysis installed and considering the ship as in-service from that date on.

Finally, to permit a comparison of maintenance cost, an average maintenance cost was calculated for each equipment as follows:

$$\frac{\text{Total maintenance cost}}{\text{AFP}} = \text{Average maintenance cost}$$

An equipment DAYS-DOWN average was calculated in the same manner. The average maintenance cost and average days-down calculated as described in this section will be used for comparison described in Chapter IV.

C. SUMMARY

This methodology described in the preceding section permits identification of a group of functionally interchangeable diesel engines based on form, fit, and function characteristics. It also permits calculation of representative maintenance costs of each diesel engine within the group with a unique APL.

The lengthy discussion of this methodology was necessary because the procedures described in the preceding section are at the heart of standardization. The methodology defined in this thesis is required because there is currently no systematic way to identify functional interchangeability among Navy HM&E equipment. This methodology described a "way around" the problem through the use of provisioning files which maintain equipment characteristics for the purpose of determining repair part requirements.

Additionally, although 3-M data has many uses, it has not been used to attempt to determine maintenance costs associated with individual equipments.

These two original approaches to the use of available data in an analysis of standardization are discussed in the following chapter.

IV. ANALYSIS AND DISCUSSION OF DATA

This section will discuss data that was collected using the methodology described in Chapter III. For purposes of this discussion, the data will be presented in three categories:

1) Functional Interchangeability Data
2) Application Data
3) Maintenance Cost Data

Data discussed in conjunction with these three categories is contained in Appendices A, B, and C.

A. FUNCTIONAL INTERCHANGEABILITY DATA

As can be seen in Appendix A, the diesel engines provisioned under LAPL 66-005 and identified by the twenty APL Numbers listed show significant commonality among the identifying alternative features (form, fit, and function characteristics) discussed in the methodology section.

BHP ranges from a low of 225 to a high of 250. The range of twenty-five BHP is small enough that, for practical application purposes, the BHP of all diesel engines listed can be considered identical. RPM at BHP ranges from 2100 to 2300. Again, this difference is inconsequential in an operating environment. All diesel engines listed have six cylinders and operate in two cycles. The bore of sixteen of the twenty APL's is identical; the remaining four APL's have only a slightly larger bore diameter. The stroke of all twenty APL's is identical. All diesel engines listed have solid type fuel injection. The commonality of these form, fit, and function characteristics among the various diesel engines show a high potential for functional interchangeability.

The remaining descriptive and identifying data in Appendix A were used for various purposes in this thesis. The National Stock Numbers (NSN's) or Navy Item Control Numbers (NICN's) (if assigned) were used to obtain the acquisition price of the diesel engines from SPCC's WSF. Acquisition prices listed in Appendix A are the equipment's Standard Price; that is, the price loaded to the WSF the last time that particular equipment was procured. Since the price is undated, the time value of money cannot be considered in an analysis incorporating this acquisition price. Two pairs of APL's have identical NSN's. No. 5 APL 666010117 and No. 9 APL 666010164 both cross to NSN 2815-00-554-1925. No. 14 APL 666010204 and No. 19 APL 666010316 both cross to NSN 2815-00-484-5966. This indicates that these four APL's may represent only two different functionally interchangeable equipments.

The Federal Supply Code for Manufacturers (FSCM) for all of the diesel engines listed is 72582, indicating they were all manufactured by Detroit Diesel, Allison Division of General Motors.

In an effort to verify that WSF Standard Prices could be considered the equipment's acquisition price and attempt to determine the effective date of these prices, Mr. Dan Robinson, Detroit Diesel Government Sales Representative, Washington, D.C. was contacted. He quoted a current government list price of $17,467 for Model #1062-4001 (No. 17 APL 666010054) which is still manufactured by Detroit Diesel (Robinson). This compares reasonably well to the WSF Standard Price of $24,750 listed in Appendix A which may include packing, shipping, and ancillary equipment costs. However, the Standard Prices listed for No. 1 APL 666010054 and No. 2 APL 666010087 apparently do not represent equipment acquisition prices. According to Mr. Robinson, Model Numbers 64HN9TEXCH and 64HN9KCL6 are World War II vintage diesels and did not cost $43,150 or $50,880 respectively, the Standard Prices listed in Appendix A. Based on this information, it is apparent that the WSF Standard Price cannot be used as an equipment's acquisition price, particularly for older equipment, in an economic analysis.

A Military Specification (MILSPEC) number which references acquisition specifications was loaded in the CCF for only two of the twenty APL's included in the analysis--and it was superceded in 1963. MIL-E-19549 (Ships) Notice -1 dated 31 January 1963 directed that:

> Future procurements for engines, diesel, propulsion for small boats and landing craft, and small auxiliary prime movers should be made under MIL-E-23457 (Ships), Engines, Diesel, Propulsion and Auxiliary, Naval Shipboard. (MIL-E-19549 (Ships), p. 1)

Since MIL-E-19549 (Ships) was superceded in 1963, it is no longer available and its contents are indeterminable. Apparently, No. 1 APL 666010054 and No. 2 APL 666010087 were the only diesels procured under a MILSPEC. The apparent lack of a MILSPEC in the procurement of the majority of the diesels implies that they were procured under performance specifications.

The SHIPPOP and FLEETPOP of the twenty APL's listed are included in Appendix A. They total 430 and 787 respectively, indicating that the twenty APL's included in the analysis are widely distributed among Navy ships and represent a sizeable population of diesel engines. The specific applications for these diesels and the Adjusted FLEETPOP totals are discussed in the next section.

B. APPLICATION DATA

Appendix B lists the applications of nineteen of the twenty APL's from Appendix A. There was no current application data for No. 4 APL 666010295, indicating it is no longer in the Navy inventory.

The application data was obta..ed from a WSF report that showed the application and quantity by hull number for each of the diesel engine APL's. It was obtained for two purposes:

- To verify that the FLEETPOP recorded in the Equipment file accurately represents the number of diesel engines for which maintenance data was collected over the period of the analysis as discussed in the methodology section,

and,

- To verify that the diesel engines included in the analysis had similar functional applications.

An inspection of Appendix A shows that there are fewer current applications than the FLEETPOP totals would indicate. There are several reasons why this discrepancy could occur including untimely or inaccurate files maintenance and time lags in loading and down-loading of the various files. Regardless, it is known that the WSF application data is more current and reliable than the Equipment File FLEETPOP data.

It is not possible to strictly account for the "missing diesels" and know exactly when they were removed from the Navy inventory without reconstructing an audit trail (an extremely difficult and time consuming procedure). Consequently, it is assumed that the majority of these diesels were not in-service during the analytical period and they were subtracted from the equipment populations. This resulted in the initial population adjustments contained in Table 1.

Further inspection of Appendix B shows that most of the ships with applications for the nineteen listed APL's were in-service long before the period of analysis. Only three APL's have applications on ships commissioned (or recommissioned after the start of the analytical period, 1 January 1984, as shown in Table 2.

TABLE 1
FLEET POPULATION ADJUSTMENTS

NO	APL	FROM FLEETPOP	TO INITIAL ADJ FLEETPOP
1	666010054	133	127
2	666010087	206	176
4	666010295	1	0
5	666010117	15	13
6	666010140	15	13
7	666010147	96	94
8	666010148	26	25
10	666010173	16	15
13	666010185	33	25

TABLE 2
COMMISSIONINGS WITHIN THE ANALYTICAL PERIOD

NO	APL	SHIP APPLICATION	COMMISSIONED	QTY
8	666010148	BB-61	4/84	[illegible]
15	666010209	BB-61	4/84	1
16	666010221	BB-61	4/84	3
		BB-63	7/86	1
		CVN-71	10/86	8
		LSD-41	2/85	1
		LSD-42	2/86	1

Using this process described in the methodology section resulted in adjusting only one FLEETPOP, No. 16 APL 666010221 from ninety to eighty-two. There was no effect on the other two FLEETPOP's once they were rounded to the nearest whole number.

A review of the application data resulted in one more reason to adjust equipment populations. No. 1, APL 666010054 and No. 2 APL 666010087 have applications on Military Sealift Command (MSC) and U.S. Coast Guard (USCG), ships as shown in Table 3.

TABLE 3
MSC AND U.S. COAST GUARD APPLICATIONS

NO	APL	SHIP APPLICATION MSC		QTY
1	666010054	TAO-105		1
		TAO-107		1
		TAO-108		2
		TAO-109		1
		TAO-143		1
		TAO-144		1
		TAO-147		2
		TAO-148		1
			TOTAL	10
		MSC		
2	666010087	TAFS-8		1
		TAGS-32		2
		USCG		
		WAGB-10		2
		WAGB-11		2
		WAGB-281		1
		WAGB-282		1
			TOTAL	9

Since MSC and USCG ships do not report under the Navy Ship's 3-M System, the equipment populations were further reduced to accurately reflect the equipment population. No. 1 APL 666010054 was adjusted from 127 to 117 and the population for No. 2 APL 666010087 was adjusted from 176 to 167.

The second purpose for obtaining the application data was to verify that the diesel engines chosen for analysis had similar applications (i.e. performed the same function). Comparative maintenance costs are more meaningful if the equipments being compared perform the same function. A review of Appendix B shows that the vast majority of the diesel engines included in this analysis have a small boat propulsion application.

The fact that all of the small boat diesel engines in this analysis came from the same manufacturer has significant implications. The factors that have led to the situation in which one manufacturer, Detroit Diesel, has apparently become the sole supplier of Navy small boat diesel engines are primarily historical. Since the end of World War II, Detroit Diesel has dominated the marine diesel engine industry which manufactures engines suitable for Navy small boat applications (Swanson). The acquisition process for Navy small boats provides only broad performance specifications for diesel engines, generally leaving the choice of a specific engine up to the boat builder. (Swanson)

Operating on a fixed-price contract basis, the boat builder naturally was drawn to the industry price leader, Detroit Diesel, as an engine supplier. Thus, the picture that begins to emerge is one in which the Navy achieved a high degree of small boat diesel engine standardization not by providing detailed design specifications, but rather as a result of market forces in the commercial marine diesel industry. It is important to point out that the Navy was well aware of what was happening and has knowingly relied on this process to select the best small boat diesels and "weed out" undesirable models (Swanson).

The implications of the situation just described, wherein one manufacturer has dominated the market, are important to bear in mind, as an attempt is made to differentiate among the various models of Detroit Diesels based on comparative maintenance costs, as discussed in the next section.

C. MAINTENANCE COST DATA

Maintenance cost data is listed in Appendix C. As previously discussed, all computations use the adjusted fleet population as an equipment population in calculating average maintenance costs. No. 4 APL 666010295 will not be considered in this analysis because there is no current application.

Since maintenance data in this thesis was collected at the APL level, the variability of maintenance costs among individual diesel engines cannot be determined. This limits the use of statistical analysis in comparing maintenance costs at the APL level. Although it may be possible to differentiate maintenance costs at the equipment serial number level using 3-M data, it will not be attempted in this thesis.

One way to compare the diesels' maintenance cost is simply to rank them based on average maintenance cost. Using the data listed in Appendix C, the APL's were ranked from lowest to highest average maintenance cost. The results are contained in Table 4.

TABLE 4
AVERAGE MAINTENANCE COST RANKINGS

RANK	NO.	APL	AVERAGE MAINTENANCE COST	ADJUSTED FLEET POP
1	14	666010204	$ 42	5
2	17	666010287	275	3
3	5	666010117	1843	13
4	19	666010316	1900	1
5	10	666010173	2806	15
6	6	666010140	5619	13
7	2	666010087	8570	167
8	12	666010177	8822	3
9	1	666010054	10,030	117
10	16	666010221	10,383	82
11	13	666010185	10,890	25
12	11	666010176	12,295	4
13	15	666010209	13,316	26
14	18	666010297	13,947	83
15	7	666010147	14,117	94
16	20	666010317	14,480	1
17	3	666010146	15,822	28
18	8	666010148	16,059	25
19	9	666010164	28,896	2

If the Adjusted Fleet Population is listed as shown above, it is apparent that the larger populations tend toward the middle of the ranking. This would indicate that there may be significant variability of maintenance cost within each APL equipment population and that a relatively large population is required to determine a reliable average maintenance cost.

Considering the significant impact that APL equipment populations appear to have on the reliability of the average maintenance cost calculated, a more meaningful comparison can be achieved by limiting the analysis to the five APL's with the largest populations. Limiting the analysis to the five APL's with the largest populations takes advantage of the "natural break" that occurs between populations at this point. (The fifth largest APL population is eighty-two, the sixth largest is twenty-six.) Limiting the analysis to these five APL's results in the ranking contained in Table 5.

TABLE 5
AVERAGE MAINTENANCE COST RANKING FOR LARGEST APL POPULATIONS

RANK	NO	APL	AFP	AVG MAINT COST
1	2	666010087	167	$ 8570
2	1	666010054	117	10,030
3	16	666010221	82	10,383
4	13	666010297	83	13,947
5	7	666010147	94	14,117

As mentioned in the methodology section, Days Down was collected from the 3-M Data Base for each APL to investigate its potential use as a qualitative variable indicating reliability. It should be noted that "Days Down" is somewhat of a misnomer. It is not a measure of the number of days that the equipment was "down" (i.e. total degradation), rather it indicates that a maintenance action was open for a certain number of days. It does not differentiate the degree of degradation, and thus it is limited in its usefulness as a reliability indicator. The results of ranking the nineteen diesel engine APL's from the lowest to highest average Days Down average are contained in Table 6.

TABLE 6
AVERAGE DAYS DOWN RANKING

RANK	NO	APL	AVG DAYS DOWN	ADJ FLEETPOP
1	17	666010287	27	3
2	14	666010204	60	5
3	5	666010117	201	13
4	12	666010177	312	3
5	10	666010173	400	15
6	11	666010176	436	4
7	16	666010221	465	82
8	18	666010297	788	83
9	2	666010087	866	167
10	1	666010054	901	117
11	13	666010185	907	25
12	8	666010148	989	25
13	20	666010317	1004	1
14	3	666010146	1008	28
15	15	666010209	1082	26
16	6	666010140	1117	13
17	7	666010147	1300	94
18	9	666010164	2018	2
19	19	666010316	2217	1

Again, the tendency for those APL's with the largest populations to tend toward the middle of the ranking is apparent, and it appears logical to again limit analysis to those five APL's with the largest populations.

For purposes of comparison, it is worthwhile to look at these average maintenance costs and average "Days Down" on an annual basis. If the average maintenance costs over the forty-four month period of the analysis are "annualized" (i.e., divided by 44 and multiplied by 12) and the same procedure is used for "Days Down" the results, ranked by annual maintenance costs are contained in Table 7.

TABLE 7
ANNUAL MAINTENANCE COST RANKING

RANK	NO	APL	ANNUAL MAINTENANCE COST	ANNUAL DAYS DOWN
1	2	666010087	$2337	236
2	1	666010054	2810	246
3	16	666010221	2832	126
4	18	666010297	3804	215
5	7	666010147	3850	355

This final ranking above provides a meaningful annual comparison of average maintenance costs and "Days Down" for the five APL's with populations considered large enough to provide reliable averages.

While it may be possible to draw some conclusions based on observable differences in the comparison above, such as:

- An apparent low ($2337), medium ($2810, 2832), and high ($3804, 3850) breakout of maintenance cost averages, and

- An apparent low (126), medium (215, 236, 246), and high (355) breakout of "Days Down" averages

given the level of accuracy attainable in an analysis such as this one, the most significant observation is that the average annual maintenance cost for all five APL's is very similar.

The observable differences in "Days Down" averages are largely inconclusive. Although there appears to be significant differences among the averages, the fact that all but one of the averages are so large (i.e., represent over half of the total 365 days in a year) limits their use as a meaningful qualitative variable. It is highly unlikely that such large "Days Down" averages provide an indication of equipment reliability. It is much more likely that "Days Down" gives an indication of how long a maintenance action is open awaiting repair parts. Since the implications of time awaiting repair parts is not directly related to research in this thesis, "Days Down" averages are not useful in a maintenance cost comparison.

D. SUMMARY

The data presented in this chapter resulted from using the methodology described in Chapter III in an attempt to obtain the comparative maintenance costs of a group of functionally interchangeable diesel engines.

This data illustrates that it is possible to determine, with reasonable assurance, a group of functionally interchangeable diesel engines based on form, fit, and function characteristics and like applications. Further, this data also illustrates that, given constraints imposed by small APL populations, it is possible to compute a representative average annual maintenance cost for the majority of the diesels included in the analysis.

The use of 3-M System "Days Down" data as an indicator of equipment reliability did not prove worthwhile. At best, it might be an indicator of the availability of repair parts, the greatest single factor influencing the time a maintenance action stays open.

Although the lack of APL population variances limited analytical techniques, it is readily apparent that there is great similarity in the average annual maintenance costs of Navy small boat diesel engines. The similarity of average annual maintenance costs is a key ingredient in an ability to draw conclusions about life cycle costing, acquisition, and standardization of Navy small boat diesel engines. These conclusions are presented in the next chapter.

V. CONCLUSIONS

Research in this thesis investigated the possibility that comparative maintenance costs, obtained from Navy Ships 3-M Data, could be used in an economic analysis of standardization. The methodology consisted of a post audit of maintenance costs for a group of functionally interchangeable equipments with the same applications that were introduced into the Navy inventory over a period of time. This thesis attempted to determine if the comparative maintenance costs of unique functionally interchangeable equipments could be useful in estimating the equipment's relative LCC. Using LCC as the basis of acquisition decisions has been described in this thesis as an appropriate way to choose a lowest-cost equipment standard for similar applications.

If the possibility of choosing an equipment standard based on economic considerations such as LCC is acknowledged, an important corollary to the research method .ogy in this thesis is a determination of the factors that have historically led to the introduction of new equipments to fill like applications. In other words, it is important to understand why new equipments were introduced in the past before proposing a methodology to choose new equipments in the future. The fact that this historical selection process may have a profound influence on th. ability to differentiate functionally interchangeable equipment based on maintenance cost became a central theme of conclusions resulting from the analysis of Navy small boat diesel engines.

The purpose of this final chapter is to offer the primary conclusions that arose from the research in this thesis. These conclusions can be divided into two categories:

A) Conclusions drawn from specific research concerning diesel engines with small boat propulsion applications that were chosen as a representative Navy HM&E equipment.

B) Conclusions drawn from broader research concerning the methodology used to determine functional interchangeability, applications, and comparative maintenance costs, and whether this methodology could be used for similar purposes for Navy HM&E equipment other than diesel engines.

A. NAVY SMALL BOAT DIESEL ENGINES

A central assumption in this thesis was that unique functionally interchangeable equipments could be identified as those equipments with unique APL numbers. This assumption was based on the specific premise of APL assignment which is to identify the unique list of maintenance significant components associated with a unique equipment as discussed earlier in this thesis. Considering the information provided by the manufacturer regarding the similarity and component interchangeability of the various Detroit Diesel models, and the commonality of form, fit, and function characteristics, the ability to accurately differentiate functionally interchangeable equipments by APL appears to be questionable. Although an analysis of the APL's themselves was beyond the scope of this thesis, it is apparent that the APL assignment process has a significant influence on the validity of an analysis such as the one conducted in this thesis. In the case of Navy small boat diesels, there is evidence to suggest that the number of unique functionally interchangeable equipments may be overstated by relying on the APL as an equipment identifier, and that a higher degree of standardization may already exist among these diesels than is indicated by APL assignment.

The research conducted in this thesis has indicated that there is no clear differentiation among the various models of diesel engines used for small boat propulsion based on maintenance cost. Therefore, it is not possible to choose a lowest-cost standard using maintenance cost as the selection criteria. However, it can be concluded that a high degree of standardization among these diesels already exists. Interestingly, this high degree of standardization did not occur as the result of a specific Navy initiated program, but as a result of market forces for commercial marine diesel engines.

One of the greatest contributions to the high degree of standardization among small boat diesels is that they were all produced by the same manufacturer--Detroit Diesel. The different models of Detroit Diesels were introduced into the Navy inventory not as the result of changing acquisition specifications, but as a result of incremental improvements in diesel technology whose incorporation led to the designation of new Detroit Diesel models. Each new Detroit Diesel model featured repair part interchangeability with previous models and standardized operating and maintenance procedures. The manufacturer maintained configuration control and simplified the logistic support problem as a matter of sound business practices. Today, Detroit Diesel guarantees the availability of repair parts for all of their diesel engines--no matter how old (Robinson).

The most significant conclusion that can be drawn from the research on small boat diesels is the implication that the Navy has allowed commercial market forces to solve the ownership cost minimization problem. Given the manner in which the ownership cost minimization problem was solved, there is little application for the methodology proposed in this thesis which attempted to differentiate among the various diesels based on comparative maintenance costs. It is also not surprising that differentiation was not possible because the diesels were similar in many respects to begin with.

B. METHODOLOGY

It is also possible to draw some conclusions about the broader issues discussed in this thesis and the methodology used to determine functional interchangeability, applications, and comparative maintenance costs. These conclusions are discussed in the next few paragraphs.

A primary conclusion that can be drawn from this research is that the Navy has not invested in maintaining data specifically to support standardization. Rather, equipment characteristics data is maintained to provide repair part support for individual equipments, not to facilitate a determination of commonality among equipments. Thus, determining commonality, as an indication of functional interchangeability, is a cumbersome and unwieldy process that uses provisioning files in a manner in which they were not designed to accommodate.

Despite the fact that provisioning files were not designed specifically to facilitate equipment interchangeable analyses, the use of form, fit, and function characteristics appears to be a useful methodology to arrive at a functionally interchangeable equipment population. Its usefulness is limited by the ability to readily determine valid form, fit, and function characteristics that accurately indicate interchangeability from those available in the CCF. These characteristics, however, cannot "stand alone". They should be used in conjunction with current application data to verify functional interchangeability. For instance, the methodology used in this thesis excluded small boat diesels with a "V" configuration as opposed to the "in line" cylinder configuration represented by the chosen form, fit, and function characteristics. Using the application data as a "first cut" would have included Detroit Diesel's more modern 6V53 model (a V6 diesel with significantly higher BHP) which is used in recently constructed Navy small boats. Thus, from an application standpoint, the 6V53 diesel should be considered functionally interchangeable. In short, an accurate determination of functionally interchangeability should be based on a balanced combination of form, fit, and function characteristics and application data.

In order to obtain statistically meaningful average maintenance costs, it is necessary to calculate maintenance cost variability within an APL population. To calculate this variability, it is necessary to determine the maintenance costs of individual equipments within an APL population. Although determining the maintenance costs of individual equipments would make data collection more difficult, and may not be possible for those equipments lacking serial number identification in the 3-M System, it would greatly enhance the quality of the analysis. This is particularly important in situations where there are many equipments with relatively small APL populations.

Finally, although the particular HM&E equipment chosen for this analysis, diesel engines, did not show a significant difference in maintenance costs among the various functionally interchangeable models, entirely different results may be obtained for other HM&E equipments. Small boat diesels appear to be somewhat of a special case where other factors have served to minimize variability. The methodology appears to be capable of providing meaningful results and could prove useful in a similar analysis of any Navy HM&E equipment.

APPENDIX A is read across pages 66 and 67 from left to right.

APPENDIX A
FUNCTIONAL INTERCHANGEABILITY DATA
(IMP letter NAVSEA-LOG-0302N TASK NO. 340224
dated September 25, 1987)

NO	LAPL	APL	BHP	RPM	CYL	CYC	BORE (IN)	STROKE (IN)	FI	FSCM
1	66-005	666010054	225	2100	6	2	4.250	5.000	SD	72582
2	66-005	666010087	225	2100	6	2	4.250	5.000	SD	72581
3	66-005	666010146	230	2300	6	2	4.250	5.000	SD	72582
4	66-005	666010295	238	2150	6	2	4.250	5.000	SD	72582
5	66-005	666010117	250	2100	6	2	4.250	5.000	SD	72582
6	66-005	666010140	250	2100	6	2	4.250	5.000	SD	72582
7	66-005	666010147	250	2300	6	2	4.250	5.000	SD	72582
8	66-005	666010148	250	2300	6	2	4.250	5.000	SD	72582
9	66-005	666010164	250	2300	6	2	4.250	5.000	SD	72582
10	66-005	666010173	250	2300	6	2	4.250	5.000	SD	72582
11	66-005	666010176	250	2300	6	2	4.250	5.000	SD	72582
12	66-005	666010177	250	2300	6	2	4.250	5.000	SD	72582
13	66-005	666010185	250	2100	6	2	4.250	5.000	SD	72582
14	66-005	666010204	250	2300	6	2	4.250	5.000	SD	72582
15	66-005	666010209	250	2300	6	2	4.250	5.000	SD	72582
16	66-005	666010221	250	2300	6	2	4.250	5.000	SD	72582
17	66-005	666010287	250	2300	6	2	4.500	5.000	SD	72582
18	66-005	666010297	250	2300	6	2	4.500	5.000	SD	72582
19	66-005	666010316	250	2300	6	2	4.500	5.000	SD	72582
20	66-005	666010317	250	2300	6	2	4.500	5.000	SD	72582

CYL - CYLINDER
CYC - CYCLE
FI - FUEL INJECTION
MANU ID - MANUFACTURER'S IDENTIFICATION NUMBER
SP - SHIPPOP
FP - FLEETPOP
AFP - ADJUSTED FLEETPOP
ACQ - ACQUISITION
NL - NOT LISTED

APPENDIX A
FUNCTIONAL INTERCHANGEABILITY DATA
(CONT'D)

NSN/NICN	MANU ID	MILSPEC	ACQ PRICE	SP	FP	AFP
2H 2815-00-132-8623	64HN9HTEXCH	19549	$43150	46	133	117
2H 2815-00-132-8940	64HN9KCLG	19549	58880	86	206	167
2S 2815-00-892-5422	6-71RD706087M	NL	11280	22	28	28
1H 0000-LL-CJ1-1714	7064-72026V71RC	NL	10000	1	1	0
2S 2815-00-554-1925	6121T6-71LCKEEL	NL	8280	8	15	13
2H 2815-00-845-1001	6-71LC6121T	NL	NL	9	15	13
NL	6087MALUM	NL	NL	84	96	94
2S 2815-00-088-7032	6088M MOD	NL	35140	17	26	25
NL	6-71RA6071MD	NL	NL	1	2	2
NL	6088 MCI	NL	NL	11	16	15
NL	6087 MST ED	NL	NL	4	4	4
2S 2815-00-489-8561	6088M PORT	NL	47810	2	3	3
2S 2815-00-554-1925	6121T6-71LC	NL	8280	21	33	25
2S 2815-00-484-5966	6072 M6-71 LC P	NL	23770	2	5	5
NL	6088MALUMG-71	NL	NL	13	26	26
2H 2815-00-462-0473	6072M6-71RC	NL	23790	31	90	82
7H 2815-00-004-2543	1062-4001	NL	24750	3	3	3
NL	1062-6001	NL	NL	67	83	83
2S 2815-00-484-5966	1062-30016-71 LC	NL	23770	1	1	1
2S 2815-00-484-5965	1062-50016-71 RA	NL	23770	1	1	1
			TOTAL	430	787	707

APPENDIX B
APPLICATION DATA
(IMP letter NAVSEA-LOG-0302N TASK NO. 340216 dated November 4, 1987; Jane's Fighting Ships)

NO	APL NUMBER	HULL NUMBER	COMM DATE	APPLICATION	QTY
1	666010054	AD-15	8/40	S/B-LCM ENGINE	2
		AD-18	3/44	S/B-ENGINE SPARE	1
				S/B-UTILITY BOAT 40 FT	3
				S/B-UTILITY BOAT 50 FT	2
		AD-19	3/44	S/B-UTILITY BOAT	3
		AD-37	7/67	S/B-UTILITY BOAT 40 FT	3
				S/B-DIVING BOAT	1
		AD-38	4/68	S/B-UTILITY BOAT 40 FT	3
				S/B-DIVING BOAT	1
		AE-25	11/59	S/B-UTILITY BOAT 33 FT	1
		AO-51	8/43	S/B-UTILITY BOAT 40 FT	2
		AO-98	10/45	S/B-LCVP ENGINE	1
				S/B-UTILITY BOAT 40 FT	1
		AOE-3	4/69	S/B-UTILITY BOAT 50 FT	2
		AOE-4	3/70	S/B-UTILITY BOAT 50 FT	2
		AOR-1	6/69	S/B-UTILITY BOAT	2
		AOR-2	11/69	S/B-UTILITY BOAT 40 FT	2
		AOR-3	6/70	S/B-UTILITY BOAT 40 FT	2
		AOR-4	12/70	S/B-UTILITY BOAT 40 FT	1
		AOR-5	11/71	S/B-UTILITY BOAT 40 FT	2
		AOR-7	10/76	S/B-UTILITY BOAT	3
		AR-6	10/42	S/B-UTILITY BOAT 40 FT	2
		AR-8	6/44	S/B-LCM ENGINE	2
				S/B-UTILITY BOAT 40 FT	1

ARL-24	12/44	F/F-EMERGENCY FIRE PUMP	1
AS-19	1/44	S/B-UTILITY BOAT 50 FT	1
AS-31	6/62	S/B-UTILITY BOAT 40 FT	2
		S/B-UTILITY BOAT	2
AS-34	11/65	S/B-UTILITY BOAT 40 FT	2
AS-36	7/79	S/B-UTILITY BOAT 40 FT	2
		S/B-UTILITY BOAT 50 FT	2
AS-37	8/71	S/B-UTILITY BOAT	6
CV-41	9/45	S/B-UTILITY BOAT 40 FT	1
CV-60	4/56	S/B-UTILITY BOAT 50 FT	4
CV-62	1/59	S/B-PERSONNEL BOAT	1
		S/B-UTILITY BOAT 50 FT	4
CV-66	1/65	S/B-UTILITY BOAT 40 FT	1
		S/B-UTILITY BOAT 50 FT	2
CV-67	9/68	S/B-UTILITY BOAT 40 FT	2
		S/B-UTILITY BOAT 50 FT	5
CVN-68	5/75	S/B-UTILITY BOAT 50 FT	2
CVN-69	10/77	S/B-UTILITY BOAT 40 FT	3
		S/B-UTILITY BOAT 50 FT	10
CVN-70	2/82	S/B-UTILITY BOAT 40 FT	2
		S/B-UTILITY BOAT 50 FT	6
CVN-71	9/86	S/B-UTILITY BOAT 50 FT	4
LPH-2	8/61	S/B-UTILITY BOAT 40 FT	1
LPH-7	7/63	S/B-UTILITY BOAT 40 FT	1
LPH-10	8/66	S/B-UTILITY BOAT 40 FT	2
LPH-11	11/68	S/B-UTILITY BOAT 40 FT	2
TAO-105	12/45	F/F-EMERGENCY FIRE PUMP	1

		TAO-107	4/46	F/F-EMERGENCY FIRE PUMP	1
		TAO-108	5/46	S/B-UTILITY BOAT	2
		TAO-109	6/46	S/B-UTILITY BOAT	1
		TAO-143	9/54	S/B-UTILITY BOAT	1
		TAO-144	1/55	F/F-FIRE PUMP INSTALLED	1
		TAO-147	11/55	S/B-UTILITY BOAT F/F-FIRE PUMP INSTALLED	1 1
		TAO-148	1/56	F/F-FIRE PUMP INSTALLED	1
				TOTAL	127
2	666010087	AD-15	8/40	S/B-UTILITY BOAT 40 FT S/B-UTILITY BOAT 50 FT	3 1
		AD-19	3/44	S/B-LCVP S/B-DIVING BOAT	1 1
		AD-37	7/67	S/B-LCM	4
		AD-38	4/68	S/B-LCM	2
		AD-41	5/80	S/B-DIVING BOAT	2
		AGF-11	5/70	S/B-LCVP	2
		AO-99	12/45	S/B-LCVP	1
		AOE-1	3/64	S/B-UTILITY BOAT	1
		AOE-3	4/69	S/B-LCVP	1
		AOE-4	3/70	S/B-LCVP	1
		AOR-6	8/73	S/B-UTILITY BOAT 40 FT	1
		AR-5	6/41	S/B-LCVP S/B-MOTORBOAT	1 1
		AR-6	10/42	S/B-LCM-M	2
		AR-8	6/44	S/B-UTILITY BOAT 40 FT S/B-DIVING BOAT	2 2

ARL-24	12/44	S/B-LCVP	2
AS-11	9/41	S/B-UTILITY BOAT	2
AS-18	9/43	S/B-UTILITY BOAT 40 FT	3
		S/B-UTILITY BOAT 50 FT	1
		S/B-LCM 6	2
AS-19	1/44	DIVING APPARATUS	1
		S/B-ENGINE SPARE	1
AS-32	9/63	S/B-UTILITY BOAT 40 FT	4
AS-37	8/71	S/B-DIVING BOAT	2
CGN-36	2/74	S/B-UTILITY BOAT	2
CGN-37	1/75	S/B-UTILITY BOAT	2
CV-60	4/56	S/B-UTILITY BOAT 40 FT	1
CVN-65	11/61	S/B-UTILITY BOAT 40 FT	2
CVN-68	5/75	S/B-UTILITY BOAT 40 FT	2
LCC-19	11/70	S/B-LCVP	2
LCC-20	1/71	S/B-LCVP	1
LHA-1	5/76	S/B-LCM 6	2
LHA-3	9/78	S/B-LCM 6	4
LPD-1	9/62	S/B-UTILITY BOAT 40 FT	2
LPD-2	5/63	S/B-UTILITY BOAT 40 FT	2
LPD-4	2/65	S/B-LCVP	2
LPD-5	6/65	S/B-LCVP	2
LPD-6	12/65	S/B-LCVP	2
LPD-7	4/67	S/B-LCVP	1
LPD-8	9/67	S/B-LCVP	2

LPD-9	10/68	S/B-LCVP	2
LPD-10	7/69	S/B-LCVP	2
LPD-12	12/70	S/B-LCVP	2
LPD-13	2/70	S/B-LCVP	2
LPD-14	3/71	S/B-LCVP	2
LPD-15	7/71	S/B-LCVP	2
LPH-12	6/70	S/B-LCVP	2
LSD-28	9/54	S/B-LCVP	2
LSD-29	11/54	S/B-LCVP	2
LSD-31	3/55	S/B-LCVP	2
LSD-32	6/56	S/B-LCVP	2
LSD-33	8/56	S/B-LCVP	1
LSD-34	12/56	S/B-LCVP	2
LSD-36	3/69	S/B-LCVP S/B-LCM 6	1 2
LSD-37	10/70	S/B-LCVP	1
LSD-38	3/71	S/B-LCVP	1
LSD-39	5/72	S/B-LCVP	1
LSD-40	12/72	S/B-LCVP S/B-LCM	1 2
LST-1179	6/69	S/B-LCVP	4
LST-1180	1/70	S/B-LCVP	3
LST-1181	6/70	S/B-LCVP	3
LST-1182	11/69	S/B-LCVP	3

		LST-1183	2/70	S/B-LCVP	3
		LST-1184	4/70	S/B-LCVP	3
		LST-1185	6/70	S/B-LCVP	3
		LST-1186	8/70	S/B-LCVP	3
		LST-1187	10/70	S/B-LCVP	3
		LST-1188	1/71	S/B-LCVP	3
		LST-1189	3/71	S/B-LCVP	3
		LST-1192	9/71	S/B-LCVP	3
		LST-1193	10/71	S/B-LCVP	3
		LST-1194	12/71	S/B-LCVP	3
		LST-1195	2/72	S/B-LCVP	3
		LST-1196	4/72	S/B-LCVP	3
		LST-1197	5/72	S/B-LCVP	3
		LST-1198	8/72	S/B-LCVP	3
		TAFS-8	12/66	S/B-UTILITY BOAT 40 FT	1
		TAGS-32	1/71	S/B-LCVP	2
		WAGB-10	1/76	S/B-LCVP	2
		WAGB-11	2/78	S/B-LCVP	2
		WAGB-281	3/43	S/B-LCVP	1
		WAGB-282	2/45	S/B-LCVP	1
				TOTAL	176
3	666010146	AE-23	5/51	S/B-PERSONNEL BOAT	1
		AE-25	11/59	S/B-PERSONNEL BOAT	1
		AE-28	7/70	S/B-PERSONNEL BOAT	2

		AE-32	11/71	S/B-PERSONNEL BOAT	2
		AE-35	12/72	S/B-PERSONNEL BOAT	2
		CG-21	5/63	S/B-PERSONNEL BOAT	1
		CG-23	7/63	S/B-PERSONNEL BOAT S/B-CAPTAIN'S GIG	1 1
		CGN-36	2/74	S/B-PERSONNEL BOAT	2
		CGN-37	1/75	S/B-PERSONNEL BOAT	2
		DD-985	9/79	S/B-PERSONNEL BOAT	1
		DDG-2	9/60	S/B-PERSONNEL BOAT	1
		DDG-5	5/62	S/B-PERSONNEL BOAT	1
		DDG-8	12/60	S/B-PERSONNEL BOAT	1
		DDG-15	12/62	S/B-PERSONNEL BOAT	1
		DDG-16	4/63	S/B-PERSONNEL BOAT	1
		DDG-17	7/63	S/B-PERSONNEL BOAT	1
		DDG-19	4/63	S/B-PERSONNEL BOAT	1
		DDG-41	11/60	S/B-PERSONNEL BOAT	1
		FF-1043	2/65	S/B-PERSONNEL BOAT	1
		FFG-3	5/68	S/B-PERSONNEL BOAT	1
		FFG-4	4/67	S/B-PERSONNEL BOAT	1
				TOTAL	28
5	666010117	LPD-1	9/62	S/B-LCP L MK11	2
		LPD-2	5/63	S/B-LCP L MK11	2
		LPD-7	4/76	S/B-LCP L	2
		LPH-7	7/63	S/B-LCP L	2

		LSD-29	11/54	S/B-LCP L MK11	2
		LSD-31	3/55	S/B-LCP L MK11	2
		LSD-32	6/56	S/B-LCP L MK11	1
					TOTAL 13
6	666010140	AGF-3	2/64	S/B-LCP L MK11	2
		AR-8	6/44	S/B-PERSONNEL BOAT 28 FT	1
		LCC-20	1/71	S/B-LCP L MK11	1
		LPD-4	2/65	S/B-LCP L MK11	2
		LPD-5	6/65	S/B-LCP L MK11	2
		LPD-6	12/65	S/B-LCP L MK11	2
		LPH-9	1/65	S/B-LCP L	2
		LST-1184	4/70	S/B-LCP L MK11	1
					TOTAL 13
7	666010147	AE-21	11/56	S/B-PERSONNEL BOAT	1
		AE-22	3/57	S/B-PERSONNEL BOAT	1
		AE-24	7/59	S/B-PERSONNEL BOAT	1
		AE-27	12/68	S/B-PERSONNEL BOAT	1
		AE-29	5/71	S/B-PERSONNEL BOAT	2
		AE-33	2/72	S/B-PERSONNEL BOAT	2
		AFS-1	12/63	S/B-PERSONNEL BOAT	2
		AFS-2	7/64	S/B-PERSONNEL BOAT	1
		AFS-4	11/68	S/B-PERSONNEL BOAT	2
		AFS-5	11/68	S/B-PERSONNEL BOAT	2
		AFS-6	5/69	S/B-PERSONNEL BOAT	2

AFS-7	10/70	S/B-PERSONNEL BOAT	1
AOE-1	3/64	S/B-PERSONNEL BOAT	1
AOR-1	6/69	S/B-PERSONNEL BOAT	1
AOR-2	11/69	S/B-PERSONNEL BOAT	2
AOR-3	6/70	S/B-PERSONNEL BOAT	1
AOR-5	11/71	S/B-PERSONNEL BOAT	1
AOR-6	8/73	S/B-PERSONNEL BOAT	1
AR-5	6/41	S/B-PERSONNEL BOAT	1
AR-6	10/42	S/B-PERSONNEL BOAT	1
AS-11	9/41	S/B-PERSONNEL BOAT	1
CG-16	8/62	S/B-PERSONNEL BOAT	1
CG-29	12/66	S/B-PERSONNEL BOAT	2
CG-30	4/67	S/B-PERSONNEL BOAT	2
CG-31	4/67	S/B-PERSONNEL BOAT	2
CG-32	7/66	S/B-PERSONNEL BOAT	1
CG-33	5/66	S/B-UTILITY BOAT	1
CG-34	1/67	S/B-PERSONNEL BOAT	2
CGN-25	10/62	S/B-PERSONNEL BOAT	1
DD-946	11/58	S/B-PERSONNEL BOAT 28 FT	1
DDG-3	2/61	S/B-PERSONNEL BOAT	1
DDG-7	12/60	S/B-PERSONNEL BOAT	1
DDG-10	6/61	S/B-PERSONNEL BOAT	1
DDG-13	6/62	S/B-PERSONNEL BOAT	1
DDG-14	2/62	S/B-PERSONNEL BOAT	1

DDG-21	3/64	S/B-PERSONNEL BOAT	1
DDG-22	9/64	S/B-PERSONNEL BOAT	1
DDG-23	3/64	S/B-PERSONNEL BOAT	1
DDG-24	8/64	S/B-PERSONNEL BOAT	1
DDG-42	8/60	S/B-PERSONNEL BOAT	1
DDG-43	4/61	S/B-PERSONNEL BOAT	1
DDG-45	12/59	S/B-PERSONNEL BOAT	1
DDG-46	5/60	S/B-PERSONNEL BOAT 28 FT	1
FF-1040	12/64	S/B-PERSONNEL BOAT	1
FF-1045	12/65	S/B-PERSONNEL BOAT	1
FF-1049	6/67	S/B-PERSONNEL BOAT	1
FF-1050	10/68	S/B-PERSONNEL BOAT	1
FF-1051	7/68	S/B-PERSONNEL BOAT	1
FF-1053	11/69	S/B-PERSONNEL BOAT	1
FF-1054	4/70	S/B-PERSONNEL BOAT	1
FF-1055	7/69	S/B-PERSONNEL BOAT	1
FF-1056	8/69	S/B-PERSONNEL BOAT	1
FF-1057	5/70	S/B-PERSONNEL BOAT	1
FF-1058	11/69	S/B-PERSONNEL BOAT	1
FF-1059	1/70	S/B-PERSONNEL BOAT	1
FF-1060	3/70	S/B-PERSONNEL BOAT	1
FF-1062	8/70	S/B-PERSONNEL BOAT	1
FF-1064	12/70	S/B-PERSONNEL BOAT	1
FF-1065	1/72	S/B-PERSONNEL BOAT	1

FF-1067	7/70	S/B-PERSONNEL BOAT	1
FF-1069	5/72	S/B-PERSONNEL BOAT	1
FF-1070	8/71	S/B-PERSONNEL BOAT	1
FF-1071	12/70	S/B-PERSONNEL BOAT	1
FF-1073	9/72	S/B-PERSONNEL BOAT	1
FF-1074	3/71	S/B-PERSONNEL BOAT	1
FF-1076	7/71	S/B-PERSONNEL BOAT	1
FF-1077	12/70	S/B-PERSONNEL BOAT	1
FF-1079	5/71	S/B-PERSONNEL BOAT	1
FF-1080	8/71	S/B-PERSONNEL BOAT	1
FF-1082	10/71	S/B-PERSONNEL BOAT	1
FF-1083	12/71	S/B-PERSONNEL BOAT	1
FF-1084	3/72	S/B-PERSONNEL BOAT	1
FF-1086	7/72	S/B-PERSONNEL BOAT	1
FF-1089	2/73	S/B-PERSONNEL BOAT	1
FF-1090	3/73	S/B-PERSONNEL BOAT	1
FF-1091	6/73	S/B-PERSONNEL BOAT	1
FF-1092	7/73	S/B-PERSONNEL BOAT	1
FF-1093	11/73	S/B-PERSONNEL BOAT	1
FF-1094	1/74	S/B-PERSONNEL BOAT	1
FF-1095	6/74	S/B-PERSONNEL BOAT	1
FF-1096	7/74	S/B-PERSONNEL BOAT	1
FF-1097	11/74	S/B-PERSONNEL BOAT	1
FF-1098	11/65	S/B-PERSONNEL BOAT	1
		TOTAL	94

8	666010148	AD-18	3/44	S/B	2
		AD-37	7/67	S/B-CAPTAIN'S GIG	2
		AO-51	8/43	S/B-CAPTAIN'S GIG	1
		AOE-1	3/64	S/B-PERSONNEL BOAT	1
		AOE-2	4/67	S/B-PERSONNEL BOAT	2
		AOR-1	6/69	S/B-PERSONNEL BOAT	1
		AOR-2	11/69	S/B-CAPTAIN'S GIG	1
		AOR-5	11/71	S/B-PERSONNEL BOAT 33 FT	1
		AOR-6	8/73	S/B-PERSONNEL BOAT 33 FT	1
		AS-11	9/41	S/B-PERSONNEL BOAT	1
		AS-18	11/43	S/B-PERSONNEL BOAT	1
		AS-19	1/44	S/B-PERSONNEL BOAT	2
				S/B-PERSONNEL BOAT 33 FT	1
		AS-32	9/63	S/B-PERSONNEL BOAT	4
		BB-61	4/84	S/B-PERSONNEL BOAT 33 FT	1
		BB-62	12/82	S/B-PERSONNEL BOAT 33 FT	2
		FF-1068	6/70	S/B-PERSONNEL BOAT	1
				TOTAL	25
9	666010164	CV-62	1/59	S/B-PERSONNEL BOAT 40 FT	2
				TOTAL	2
10	666010173	AD-15	8/40	S/B-PERSONNEL BOAT 33 FT	2
		AD-18	3/44	S/B-PERSONNEL BOAT 33 FT	1
		AOR-3	6/70	S/B-PERSONNEL BOAT 33 FT	1
		AR-6	10/42	S/B-PERSONNEL BOAT 33 FT	1
		AS-18	9/43	S/B-PERSONNEL BOAT 33 FT	1

		AS-31	6/62	S/B-PERSONNEL BOAT	4
		AS-33	11/64	S/B-PERSONNEL BOAT 33 FT	1
		AS-34	11/65	S/B-PERSONNEL BOAT 33 FT	2
		CV-61	8/57	S/B-CAPTAIN'S GIG	1
		CV-64	10/61	S/B-CAPTAIN'S GIG	1
				TOTAL	15
11	666010176	AS-18	9/43	S/B-PERSONNEL BOAT	1
		CG-16	8/62	VENTILATION SYSTEM	1
		DD-964	2/76	S/B-PERSONNEL BOAT	1
		DD-972	3/78	S/B-PERSONNEL BOAT	1
				TOTAL	4
12	666010177	AOR-6	10/42	S/B-PERSONNEL BOAT 33 FT	1
		DD-967	1/76	S/B-PERSONNEL BOAT	2
				TOTAL	3
13	666010185	AGF-11	5/70	S/B-ADMIRAL'S BARGE	1
		ASR-21	4/73	S/B-MOTOR WORK BOAT	1
		LCC-19	11/70	S/B-LCP L MK11	2
		LCC-20	1/71	S/B-PERSONNEL BOAT 33 FT	1
		LHA-2	10/77	S/B-LCP L MK11	1
		LHA-3	9/78	S/B-LCP L MK11	1
		LPD-9	10/68	S/B-LCP L MK11	3
		LPD-14	3/71	S/B-LCP L MK11	2
		LPD-15	7/71	S/B-LCP L MK11	2
		LPH-10	8/66	S/B-LCP L MK11	2
		LPH-11	11/68	S/B-LCP L MK11	2

		LSD-28	9/54	S/B-LCP L MK11	1
		LSD-34	12/56	S/B-LCP L MK11	1
		LSD-36	3/69	S/B-LCP L MK11	2
		LST-1181	6/70	S/B-LCP L MK11	1
		LST-1194	12/71	S/B-LCP L MK11	1
		LST-1198	8/72	S/B-LCP L MK11	1
				TOTAL	25
14	666010204	CV-66	1/65	S/B-PERSONNEL BOAT 40 FT	3
		CVN-69	10/77	S/B-PERSONNEL BOAT 40 FT	2
				TOTAL	5
15	666010209	AD-18	3/44	S/B-PERSONNEL BOAT 33 FT	2
		AD-38	4/68	S/B-PERSONNEL BOAT 33 FT	3
		AOE-3	4/69	S/B-PERSONNEL BOAT	2
		AOE-4	3/70	S/B-PERSONNEL BOAT 33 FT	3
		AOR-4	12/70	S/B-PERSONNEL BOAT	1
		AR-8	6/44	S/B-MOTORBOAT	1
				S/B-PERSONNEL BOAT 33 FT	1
		AS-36	2/70	S/B-PERSONNEL BOAT	3
		AS-37	8/71	S/B-PERSONNEL BOAT	4
		BB-61	4/84	S/B-PERSONNEL BOAT 33 FT	1
		CV-41	9/45	S/B-PERSONNEL BOAT 33 FT	1
		CV-43	10/47	S/B-PERSONNEL BOAT	1
		CV-63	4/61	S/B-ADMIRAL'S BARGE	1
		LCC-19	11/70	S/B-PERSONNEL BOAT 33 FT	2
				TOTAL	26

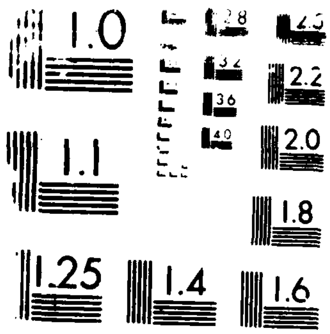
16	666010221	AD-41	5/80	S/B-PERSONNEL BOAT 40 FT	6
				S/B-UTILITY BOAT	2
		AD-42	6/81	S/B-DIVING BOAT	1
				S/B-PERSONNEL BOAT	3
				S/B-UTILITY BOAT	2
		AD-43	4/82	S/B-DIVING BOAT	1
				S/B-PERSONNEL BOAT 40 FT	3
				S/B-UTILITY BOAT	2
		AD-44	12/83	S/B-UTILITY BOAT 50 FT	3
				S/B-DIVING BOAT	1
		AGF-3	2/64	VENTILATION SYSTEM	1
		AO-99	12/45	S/B-UTILITY BOAT	1
		AO-177	1/81	S/B-UTILITY BOAT	1
		AO-178	9/81	S/B-UTILITY BOAT 40 FT	1
		AO-179	11/81	S/B-UTILITY BOAT 40 FT	1
		AO-180	12/81	S/B-UTILITY BOAT 40 FT	1
		AO-186	4/83	S/B-UTILITY BOAT 40 FT	1
		AR-5	6/41	S/B-UTILITY BOAT 50 FT	2
		AR-8	6/44	S/B-UTILITY BOAT 40 FT	1
		AR-34	11/65	S/B-UTILITY BOAT	1
		AS-40	2/80	S/B-UTILITY BOAT 40 FT	2
				S/B-UTILITY BOAT 50 FT	2
		AS-41	9/81	S/B-UTILITY BOAT 40 FT	2
				S/B-UTILITY BOAT 50 FT	2
		BB-61	4/84	S/B-UTILITY BOAT 40 FT	3
		BB-62	12/82	S/B-UTILITY BOAT 40 FT	3
		BB-63	7/86	S/B-PERSONNEL BOAT 33 FT	1
		CV-41	9/45	S/B-PERSONNEL BOAT 40 FT	1

		CV-59	10/55	S/B-PERSONNEL BOAT 40 FT	2
				S/B-UTILITY BOAT 50 FT	4
		CV-60	4/56	S/B-PERSONNEL BOAT 40 FT	2
		CV-66	1/65	S/B-UTILITY BOAT 50 FT	3
		CV-67	9/68	S/B-PERSONNEL BOAT 40 FT	3
		CVN-65	11/61	S/B-PERSONNEL BOAT 40 FT	1
		CVN-68	5/75	S/B-PERSONNEL BOAT 40 FT	4
		CVN-69	10/77	S/B-PERSONNEL BOAT 40 FT	5
		CVN-70	2/82	S/B-PERSONNEL BOAT 40 FT	4
		CVN-71	10/86	S/B-PERSONNEL BOAT 40 FT	8
		FFG-6	11/67	S/B-PERSONNEL BOAT	1
		LSD-41	2/85	S/B-UTILITY BOAT 50 FT	1
		LSD-42	2/86	S/B-UTILITY BOAT 50 FT	1
				TOTAL	90
17	666010287	AD-38	4/68	S/B-PERSONNEL BOAT 33 FT	1
		AO-98	10/45	S/B-CAPTAIN'S GIG	1
		AS-31	6/62	S/B-PERSONNEL BOAT	1
				TOTAL	3
18	666010297	AD-41	5/80	S/B-PERSONNEL BOAT 33 FT	3
		AD-42	6/81	S/B-PERSONNEL BOAT 33 FT	3
		AD-43	4/82	S/B-PERSONNEL BOAT 33 FT	3
		AD-44	12/83	S/B-PERSONNEL BOAT 33 FT	3
		AE-27	12/68	S/B-PERSONNEL BOAT	1
		AE-34	6/72	S/B-PERSONNEL BOAT	1
		AO-99	6/45	S/B-PERSONNEL BOAT	1

AOR-7	10/76	S/B-PERSONNEL BOAT	2
AS-11	9/41	S/B-PERSONNEL BOAT	1
AS-39	7/79	S/B-PERSONNEL BOAT 33 FT	2
AS-40	2/80	S/B-PERSONNEL BOAT 33 FT	2
AS-41	8/81	S/B-PERSONNEL BOAT 33 FT	2
CG-17	2/63	S/B-PERSONNEL BOAT	1
CG-19	11/63	S/B	1
CG-20	6/64	S/B-PERSONNEL BOAT	1
CG-22	12/63	S/B	1
CG-24	5/64	S/B-PERSONNEL BOAT	1
CG-27	5/65	S/B-PERSONNEL BOAT	1
CG-28	1/66	S/B-PERSONNEL BOAT S/B-ADMIRAL'S BARGE	1 1
CG-32	7/66	S/B-PERSONNEL BOAT	1
CGN-9	9/61	S/B-PERSONNEL BOAT	2
CGN-35	5/67	S/B	1
CGN-38	9/76	S/B-PERSONNEL BOAT	1
DD-963	9/75	S/B-PERSONNEL BOAT	1
DD-965	7/76	S/B-PERSONNEL BOAT	1
DD-966	9/76	S/B-PERSONNEL BOAT	1
DD-968	1/76	S/B-PERSONNEL BOAT	1
DD-969	7/77	S/B-PERSONNEL BOAT	1
DD-970	10/77	S/B-PERSONNEL BOAT	1
DD-971	11/77	S/B-PERSONNEL BOAT	1
DD-973	5/78	S/B-PERSONNEL BOAT	1

AD-A188 844 STANDARDIZATION USING COMPARATIVE MAINTENANCE COSTS IN AN ECONOMIC ANALYSIS(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA R N CLARK DEC 87 2/2

UNCLASSIFIED F/G 15/5 NL


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

DD-974	9/78	S/B-PERSONNEL BOAT	2
DD-975	12/77	S/B-PERSONNEL BOAT	1
DD-976	3/78	S/B-PERSONNEL BOAT	1
DD-977	6/78	S/B-PERSONNEL BOAT	1
DD-978	9/78	S/B-PERSONNEL BOAT	1
DD-979	10/78	S/B-PERSONNEL BOAT	1
DD-980	12/78	S/B-PERSONNEL BOAT	1
DD-981	3/79	S/B-PERSONNEL BOAT	1
DD-982	5/79	S/B-PERSONNEL BOAT	1
DD-984	9/79	S/B-PERSONNEL BOAT	1
DD-986	11/79	S/B-PERSONNEL BOAT	1
DD-987	12/79	S/B-PERSONNEL BOAT	1
DD-988	2/80	S/B-PERSONNEL BOAT	1
DD-989	3/80	S/B-PERSONNEL BOAT	1
DD-990	4/80	S/B-PERSONNEL BOAT	1
DD-991	5/80	S/B-PERSONNEL BOAT	1
DD-992	7/80	S/B-PERSONNEL BOAT	1
DD-997	3/83	S/B-PERSONNEL BOAT	1
DDG-11	10/61	S/B-PERSONNEL BOAT	1
DDG-18	12/62	S/B-PERSONNEL BOAT	1
		S/B	1
DDG-24	9/64	S/B	1
DDG-39	11/61	S/B	1
DDG-44	11/61	S/B-PERSONNEL BOAT	1
DDG-45	12/59	S/B-PERSONNEL BOAT	1

		DDG-993	6/81	S/B-PERSONNEL BOAT	1
		DDG-994	9/81	S/B-PERSONNEL BOAT	1
		DDG-995	10/81	S/B-PERSONNEL BOAT	1
		DDG-996	3/82	S/B-PERSONNEL BOAT	1
		FF-1043	2/65	S/B	1
		FF-1047	11/66	S/B-PERSONNEL BOAT	1
		FF-1052	4/69	S/B-PERSONNEL BOAT	1
		FF-1066	4/71	S/B-PERSONNEL BOAT	1
		FF-1087	9/72	S/B-PERSONNEL BOAT	1
		FF-1088	11/72	S/B-PERSONNEL BOAT	1
		FF-1096	7/74	S/B	1
		FFG-5	9/67	S/B-PERSONNEL BOAT	1
				TOTAL	83
19	666010316	CVN-68	5/75	S/B-UTILITY BOAT 50 FT	1
				TOTAL	1
20	666010317	AD-38	4/68	S/B-LCM 6	1
				TOTAL	1

S/B - SMALL BOAT
F/F - FIRE FIGHTING
LCM - LANDING CRAFT MECHANIZED
LCP - LANDING CRAFT PERSONNEL
LCVP - LANDING CRAFT VEHICLE/PERSONNEL

APPENDIX C
MAINTENANCE COST DATA
PERSONNEL COST
(3-M TYCOM System Data Base Retrieval
dated October 22, 1987)

NO	AFP	APL	JCN	SF MHRS	SF PRS COST	IMA MHRS	IMA PRS COST	TOTAL PERS COST
1	117	666010054	1050	9557	$129497	16559	$271567	$401065
2	167	666010087	1534	10013	135676	32649	535443	671119
3	28	666010145	357	3653	49498	6373	104517	154015
4	0	666010295	0	0	0	0	0	0
5	13	666010117	50	77	1043	76	1246	2290
6	13	666010140	192	517	7005	350	5740	12745
7	94	666010147	1248	13434	182031	24897	408015	590046
8	25	666010148	353	3199	43346	6322	103681	147027
9	2	666010164	50	288	3902	343	5625	9528
10	15	666010173	39	729	9878	522	8561	18439
11	4	666010176	29	234	3171	808	13251	16422
12	3	666010177	16	205	2778	379	6216	8993
13	25	666010185	345	1860	25203	5431	89068	114271
14	5	666010204	2	6	81	0	0	81
15	26	666010209	189	1830	24796	3328	54579	79376
16	82	666010221	376	26658	361216	6937	113767	474983
17	3	666010287	2	11	149	0	0	149
18	83	666010297	760	10954	148427	17970	294708	443135
19	1	666010316	11	138	1870	0	0	1870
20	1	666010317	14	121	1640	345	5658	7298

APPENDIX C
MAINTENANCE COST DATA
PARTS COST

NO	AFP	APL	JCN	PARTS COST	IMA PARTS COST	TOTAL PARTS COST
1	117	666010054	1050	$551579	$220824	$772403
2	167	666010087	1534	557944	202095	760039
3	28	666010146	357	217902	71097	288999
4	0	666010295	0	0	0	0
5	13	666010117	50	17910	3763	21673
6	13	666010140	192	48369	11930	6299
7	94	666010147	1248	516416	220504	736920
8	25	666010148	353	176921	77527	254448
9	2	666010164	50	42578	5686	48264
10	15	666010173	39	13025	10629	23654
11	4	666010176	29	17179	15578	32757
12	3	666010177	16	9418	8056	17474
13	25	666010185	345	113341	44660	158001
14	5	666010204	2	126	0	126
15	26	666010209	189	202383	64448	266831
16	82	666010221	376	240672	135720	376392
17	3	666010287	2	675	1	675
18	83	666010297	760	549363	165078	714441
19	1	666010316	11	30	0	30
20	1	666010317	14	3896	3286	7182

APPENDIX C
MAINTENANCE COST DATA
MAINTENANCE COST/DAYS DOWN

NO	AFP	APL	JCN	TOTAL MAINT COST	TOTAL DAYS DOWN	AVG MAINT COST	AVG DAYS DOWN
1	117	666010054	1050	$1173467	105440	$10030	901
2	167	666010087	1534	1431158	144642	8570	866
3	28	666010146	357	443014	28217	15822	1008
4	0	666010295	0	0	0	0	0
5	13	666010117	50	23963	2616	1843	201
6	13	666010140	192	73044	14515	5619	1117
7	94	666010147	1248	1326966	122181	14117	1300
8	25	666101148	353	401475	24714	16059	989
9	2	666010164	50	57792	4035	15441	951
10	15	666010173	39	42093	6000	2806	400
11	4	666010176	29	29179	1745	12295	436
12	3	666010177	16	26467	935	8822	312
13	25	666010185	345	272272	22686	10890	907
14	5	666010204	2	207	299	42	60
15	26	666010209	189	346207	28130	13316	1082
16	82	666010221	376	851375	38098	10383	465
17	3	666010287	2	824	82	275	27
18	83	666010297	760	1157575	65410	13947	788
19	1	666010316	11	1900	2217	1900	2217
20	1	666010317	14	14480	1004	14480	1004

LIST OF REFERENCES

3-M TYCOM Terminal System Users Manual. Undated. Mechanicsburg, PA: Navy Material Support Office.

An Overview of the Defense Standardization and Specification Program (DSSP). 1983. Washington, D.C.: Office of the Undersecretary of Defense for Research and Engineering.

Brown, Al. NAVSEA Code 56X3B. Phone conversation of 22 October 1987.

Institute of Modern Procedures, Inc. (IMP) letter NAVSEA-LOG-0302N Task No. 340224 of 25 September 1987.

-----TASK No. 340216 of 4 November 1987.

Integrated Logistics Support Guide. Undated. Fort Belvoir, VA: Defense Systems Management College.

Jones, Dick. Undated. HM&E Standardization. An unpublished paper.

-----. NAVSEALOGCEN Code 76. Phone conversation of 17 November 1987.

McGraw-Hill Encyclopedia of Engineering. 1983. New York: McGraw-Hill, Inc.

MIL-E-19549 (Ships) Notice -1. 1963. Military Specification Engines, Diesel, Propulsion for Small Boats and Landing Craft, and Small Auxiliary Prime Movers. Washington, D.C.: Naval Sea Systems Command.

MIL-E-23457B (Ships). 1976. Military Seecification Engines, Diesel Marine, Porpulsion and Auxiliary Medium Speed. Washington, D.C.: Naval Sea Systems Command.

Moore, John, ed. 1986. Jane's Fighting Ships 1986-87. London: Jane's Publishing Company.

NAVCOMPT Notice 7041. 1987. Composite Standard Military Rates, Basic Allowance for Quarters Rates, and Permanent Change of Station Exchange Rates Effective 1 October 1986. Washington, D.C.: Office of the Comptroller.

NAVSEA 790-AB-URM-010/3-N. 1984. Ships Maintenance and Material Management Data System Users Manual. Washington, D.C.: Naval Sea Systems Command.

NAVSUPINST 4000.32. 1971. Life-Cycle Costing. Washington, D.C.: Naval Supply Systems Command.

Office of Management and Budget Circular No. A-109. 1976. Major Systems Acquisitions. Washington, D.C.: Office of Management and Budget.

Robinson, Don. Detroit Diesel Government Sales Representative. Phone conversation of 17 November 1987.

SPCCINST 4441.170. 1984. COSAL (Consolidated Shipboard Allowance Parts List) Use and Maintenance Manual. Mechanicsburg, PA: Ships Parts Control Center.

SECNAVINST 4000.31. 1970. Life-Cycle Costing. Washington, D.C.: Office of the Secretary of the Navy.

Swanson, Eric. NAVSEA Code 56X33. Phone conversation of 19 November 1987.

Toth, Robert B. 1984. The Economics of Standardization Minneapolis, MN: Standards Engineering Society.

U.S. Department of Defense. 1979. DOD Dictionary of Military and Associated Terms. Washington, D.C.: Department of Defense.

-----DODINST 4151.7. Undated. Uniform Technical Documentation for Use in Provisioning of End Items of Material. Washington, D.C.: Department of Defense.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, VA 22304-6145	2
2.	Defense Logistics Studies Exchange U.S. Army Logistics Management Center Fort Lee, VA 23801	1
3.	Library, Code 0142 Naval Postgraduate School Monterey, CA 93943-5002	2
4.	Mr. Dick Jones Naval Sea Logistics Center Code 76 5450 Carlisle Pike PO Box 2060 Mechanicsburg, PA 17055	1
5.	Dr. Paul M. Carrick Code 54Ca Naval Postgraduate School Monterey, CA 93943-5100	1
6.	Dr. Les Zambo Code 54Za Naval Postgraduate School Monterey, CA 93943-5100	1
7.	LCDR Roger N. Clark Navy Regional Contracting Center Bldg. 600 U.S. Navy Base Philadelphia, PA 19112-5082	1

END
DATE
FILMD
3-88
DTIC